

SAE

Journal

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AUGUST 1955

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Of the 4,132,604 passenger cars produced
from Jan. 1 to May 14, 1955...almost half* were
equipped with the **NEW**



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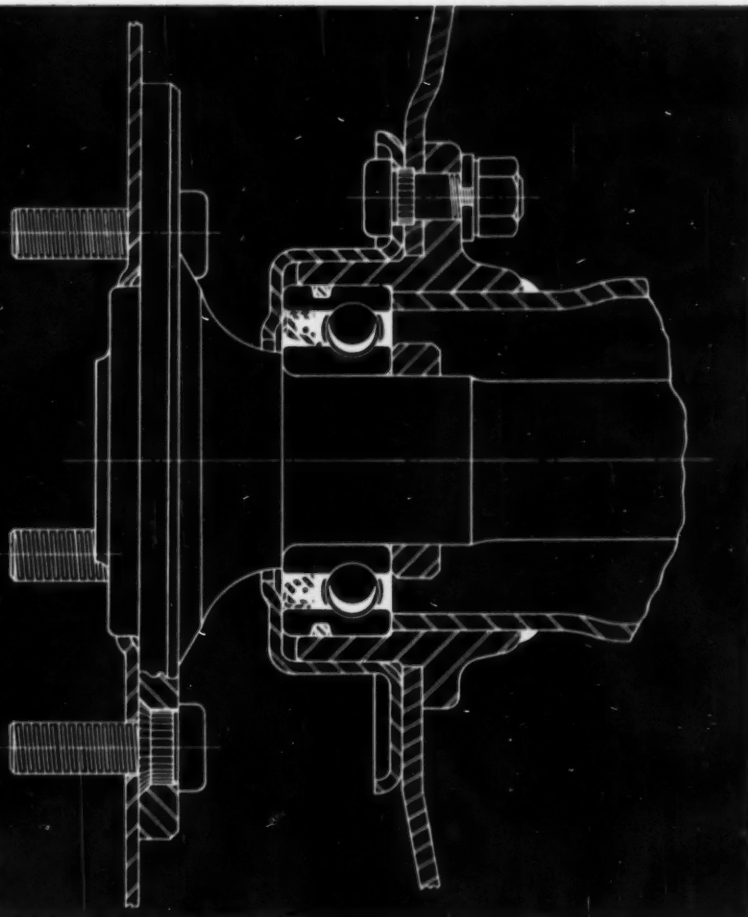
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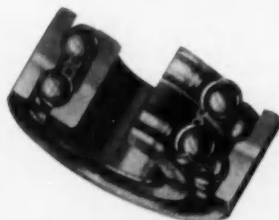
**Another
New Departure
in the
AUTO
INDUSTRY!**



**Lubricated-for-Life
Ball Bearing**



**Fan and Pump Shaft
Ball Bearing**



**Double-Row Angular-
Contact Ball Bearing**



In an industry where dollars and sense savings really count for every component, New Departure has introduced in the past many money-, space- and maintenance-saving designs. Among these "New Departures" are the self-sealed pump shaft ball bearing, the double-row angular-contact and lubricated-for-life ball bearings.

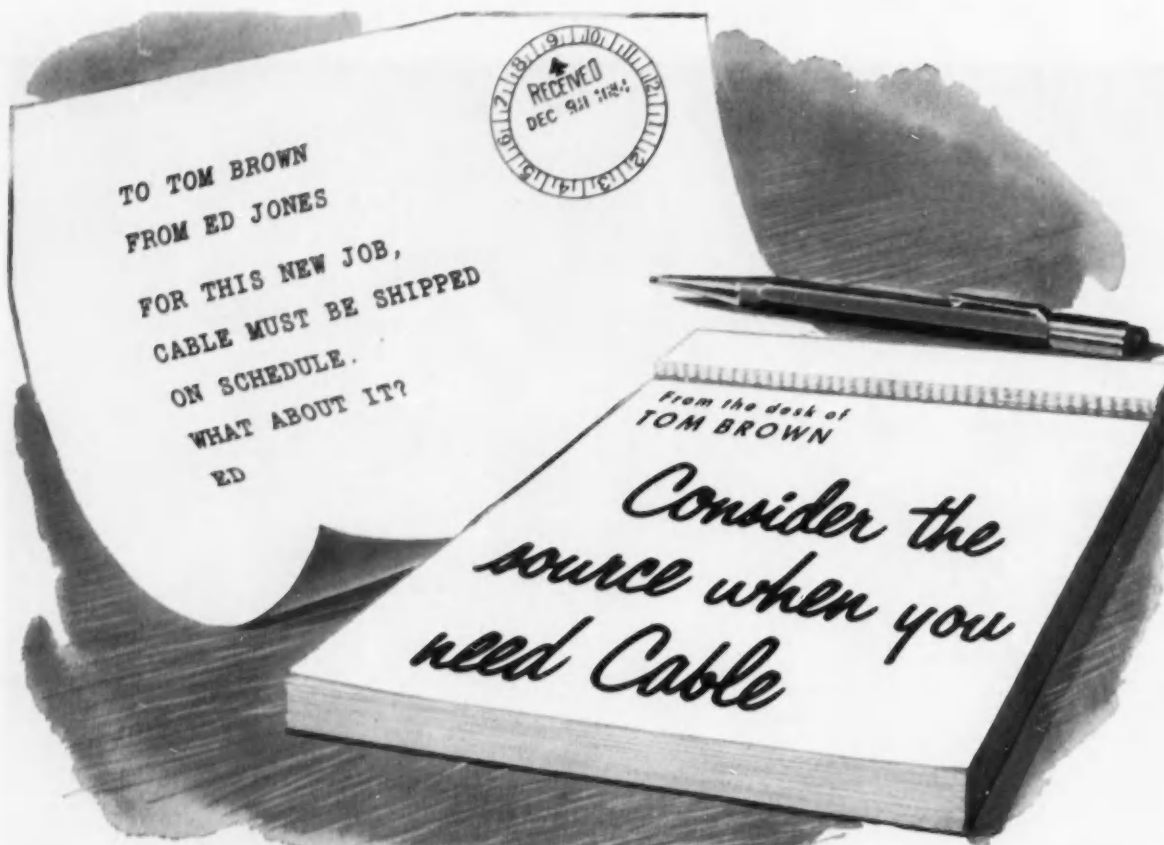
The drawing, above, illustrates New Departure's latest contribution in cost-cutting designs . . . a new rear wheel bearing. Here, the seal for the wheel mounting is located within the precision rings of the bearing, providing maximum sealing efficiency. An "O" ring on the outside diameter prevents seepage of axle oil past the bearing outer ring.

The result? A simplified mounting that greatly reduces machining operations and axle parts . . . permits easier, quicker servicing. New Departure, Division of General Motors, Bristol, Connecticut.

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Offices in Detroit, Chicago, and Oakland, California

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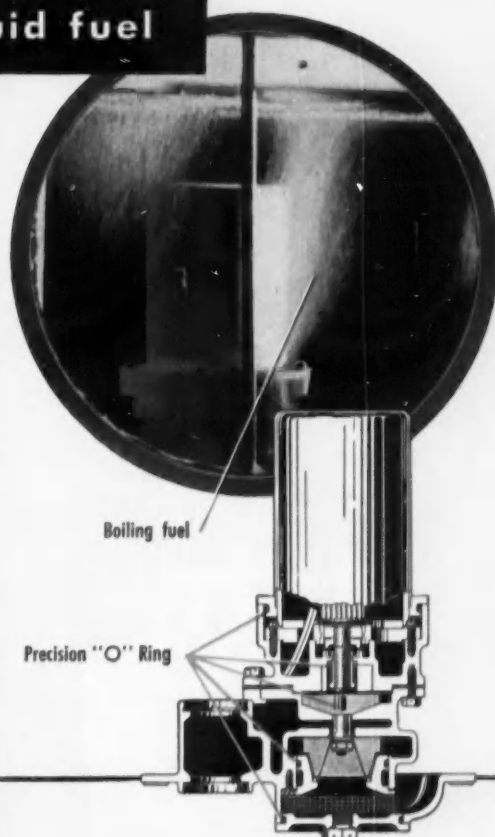


insure constant flow of liquid fuel

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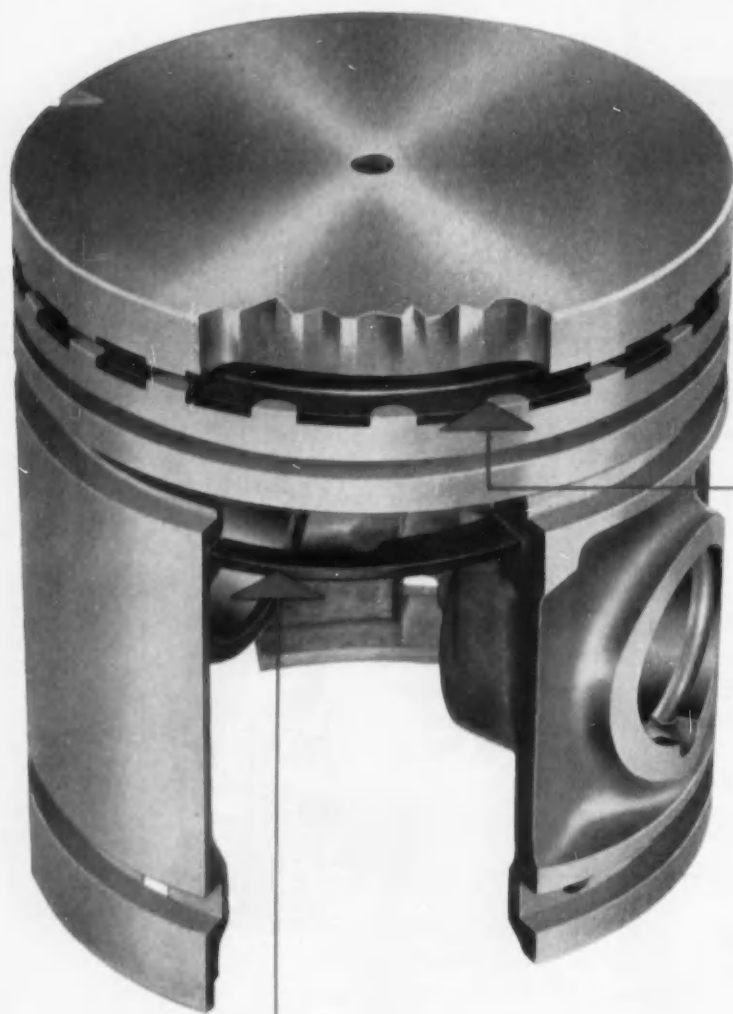
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STEERING

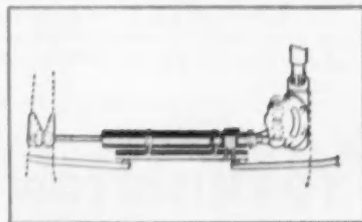
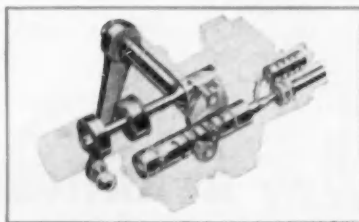
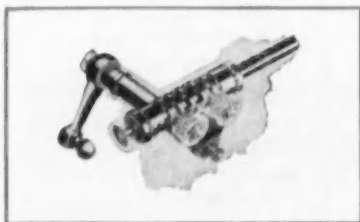
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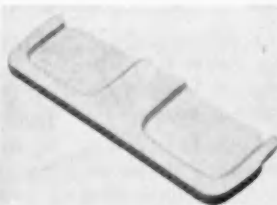
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Exciting new seating ideas become practical with AIRFOAM



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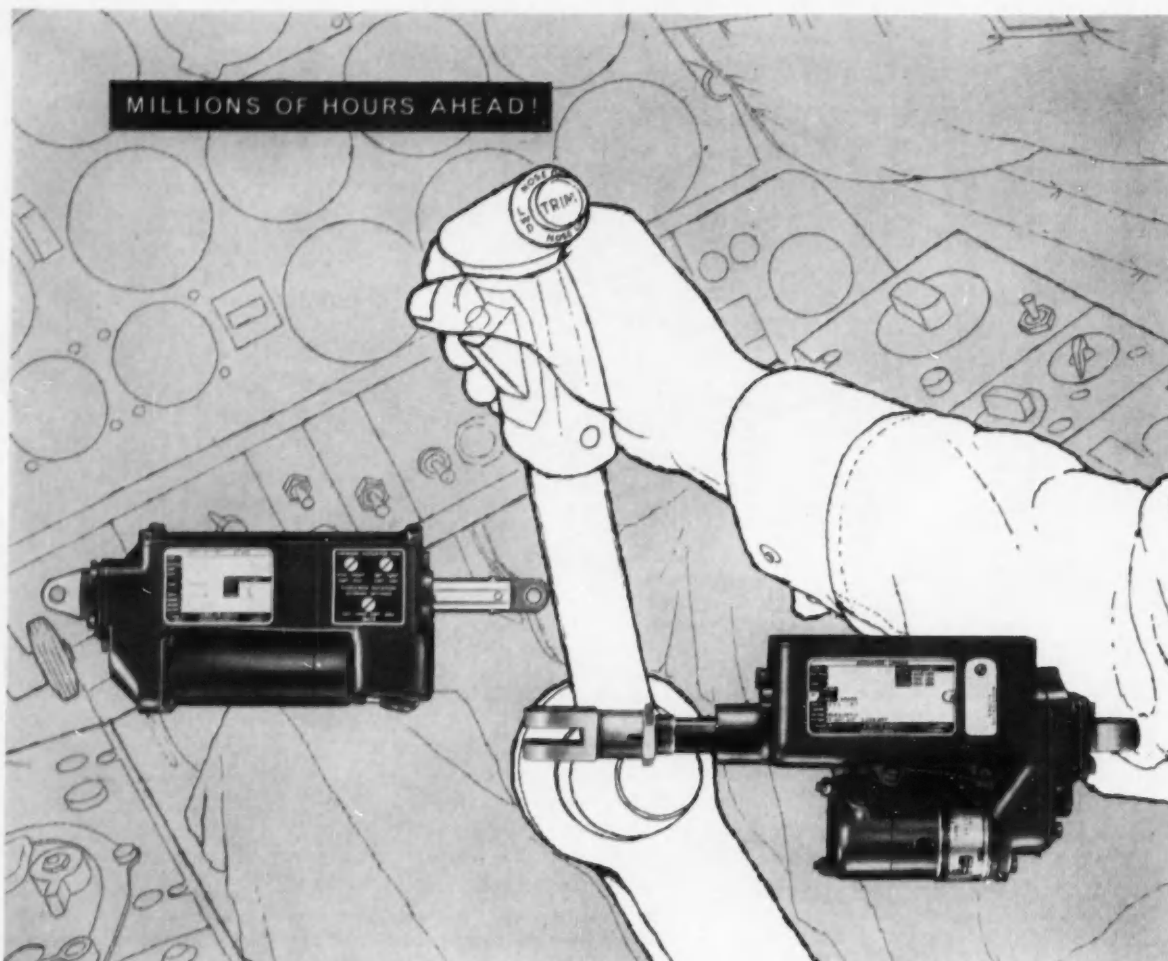
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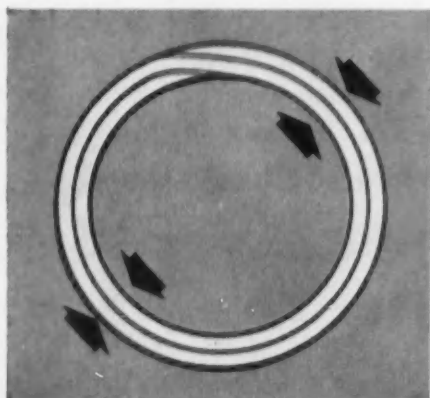
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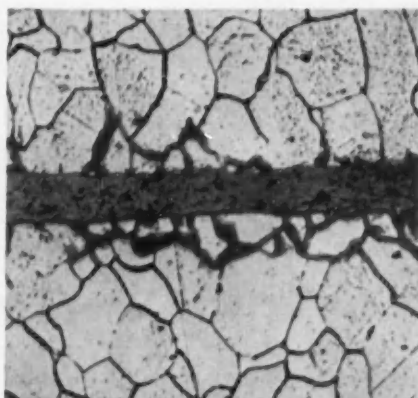
Only Bundyweld steel tubing

Here's why Bundyweld STEEL Tubing is used on 95% of today's cars

The illustrations below reveal why Bundyweld is specified by automotive manufacturers where strength and durability of tubing are essential. Bundyweld is the only tubing double-walled from a single metal strip. This exclusive process gives Bundyweld superior strength properties. Yet, because of the conditions under which Bundyweld is brazed and cooled, it is uniform and easy to fabricate.



With Bundyweld's beveled edges and single close-tolerance strip, there's no inside bead. The tubing is uniformly smooth, both inside and out. It fabricates easily; can be bent to short radii. Copper coating, inside and out, facilitates soldering and brazing operations.



This view of Bundyweld's copper bond (enlarged 300 times) shows how the copper actually alloys with the steel . . . through 360° of wall contact. That's the secret of Bundyweld's outstanding resistance to high pressure and vibration fatigue.



WHY BUNDYWELD IS BETTER TUBING



Bundyweld starts as a single strip of copper-coated steel. Then it's . . .



continuously rolled twice around laterally into a tube of uniform thickness, and



passed through a furnace. Copper coating fuses with steel. Result . . .



Bundyweld, double-walled and brazed through 360° of wall contact.



NOTE the exclusive Bundy-developed beveled edges, which afford a smoother joint, absence of bead, and less chance for any leakage.

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TO 1/2" O.D.

can take punishment like this!



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Extra-strong Bundyweld Tubing is specified for

hydraulic brake lines, to assure safe stops; for oil lines, to save costly repairs; for gasoline lines, to assure leakproof performance; for push rods, to produce more powerful overhead valve engines.

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For the Sake of Argument

Errors Are Opportunities . . .

By Norman G. Shidle

How much is accomplished by pointing out over and over again what is wrong, pinning the error on the error-maker? How many reformations have been wrought in response to a rousing: "Holy Cats!"?

Psychologists insist rehearsing the wrong imprints the error or the poor method more strongly in a man's mind. It makes him fear he will make the same mistake again . . . and he often does, *because* he fears.

He rarely improves until his mind is so filled with the right way that no room is left in it for the wrong way. . . . And it's pretty hard to imprint the right while talking—or even screaming—about how wrong the wrong is.

The fellow who can react automatically to a subordinate's error with: "OK, what shall we do next?" saves himself much frustration—and his associates, too.

The what-shall-we-do-next reaction often puts minds into constructive action instead of fruitless friction. And it may reduce the chances of the same kind of error next time.

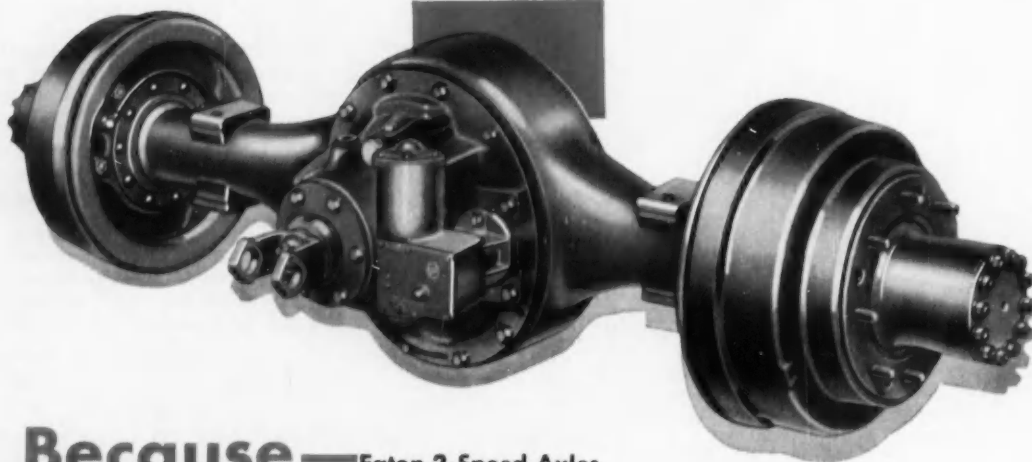
One supervisor, checking results from this approach, says he's learning something new from almost every experience with it.

"I've just realized," he says, "that I'm 'educating' a mistake-maker every time I face him or his mistake. Say I fly at him—or do a slow-burn. Then, I'm teaching him to avoid me if he possibly can when an error might possibly arise. I am decreasing my chances to help him next time 'before it is too late.'"

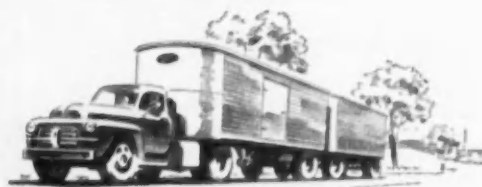
"But, suppose I pitch in to make him figure out with me what *we* should do about the already spilt milk. I'm teaching him how to mop up by himself next time . . . (and there *is* a next time for every one of us).

"Then, after the immediate problem is settled, I find both of us in better shape to explore some means to prevent future errors. Making this exploration together, he gets a chance to see how to go about error prevention. He participates in the reasoning, the procedure, and the final synthesis which focuses right conclusions. In short, he learns something he can apply a little better himself the next time. . . . And so do I!"

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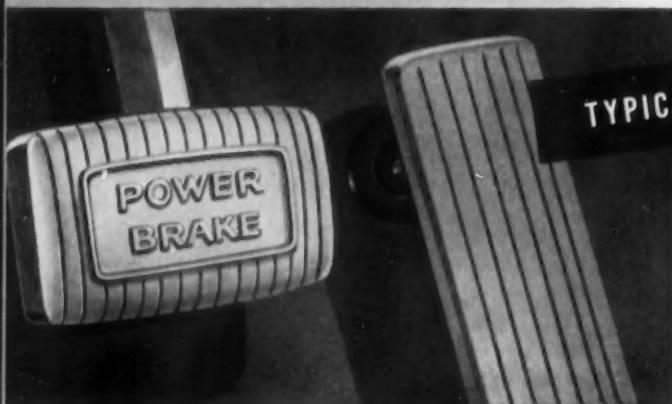
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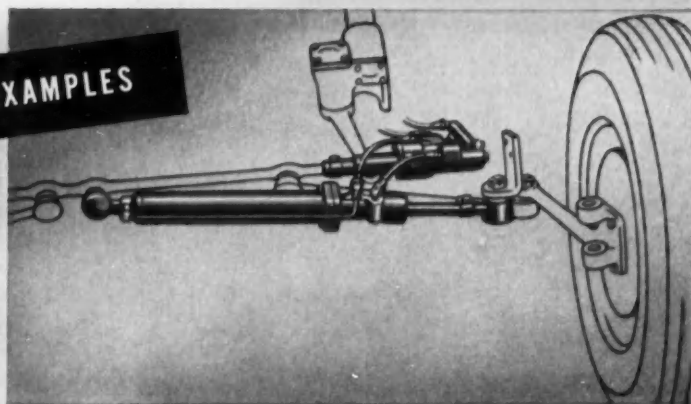
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BENDIX LOW PEDAL POWER BRAKE—Specified by more car manufacturers than any other make, Bendix* Low Pedal Power Brake makes possible quick, sure stops by merely pivoting the foot from the go to the stop control. No need to lift the foot and exert leg power to bring the car to a stop. Result—more driving comfort, less fatigue and greater safety!

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The Creative Process . . .

. . . combines past with present experience in such a fashion that one arrives at new combinations, patterns and configurations that better satisfy some need of man. It is not completed until one produces tangible evidence that the need has been satisfied.

John E. Arnold, Massachusetts Institute of Technology

Based on paper "Creativity in Engineering" presented at SAE Mid-Michigan Section, Nov. 15, 1954

PRACTICALLY all business and most engineering problems ask for creative solutions. They involve not only analysis and synthesis—as does a purely analytical problem—but evaluation as well. They are subject to a good many adequate answers. There usually is no one right answer—as is the case with the analytical problem . . . and to "produce tangible evidence that the need has been satisfied" involves a solution that looks forward, not backward, in its time orientation.

The creative process is a unique process, wholly independent of the human activity area in which it is being exercised. The artist, the poet, the composer, the businessman and the engineer use the same process but with different tools.

This may account for the fact that a great many highly creative people exercised their talent in more than one field. Albert Schweitzer is an outstanding example of this.

The mind which supplies the creative process by which the solution comes, may or may not be high in mental or intellectual capacities. People can be highly intellectual, highly analytical and judicial without being productive in a creative fashion.

But the mind which best applies this creative process does seem to have a number of characteristics which differentiate it from those which are less creative. Regardless of limiting conditions, for instance, the creative person has more ideas per unit of time than the non-creative. He is somehow able to rule out judgement during the idea-forming stage so he can get many ideas, both good and bad.

He has the ability, too, to jump from one approach to another without difficulty or without losing sight of the main goal. He is little afflicted by "functional fixedness." He wouldn't be found among the students who, well trained in use of knife switches in problems of electrical circuitry, had great difficulty in seeing the knife switch as anything but a switch.

Knife Switch or Pendulum?

Asked to construct a pendulum from materials at hand, the creative person whose only heavy piece at hand was a knife switch would probably be able to see its use in making a pendulum. Those high in

"functional fixedness" saw it only as a piece of electrical equipment.

Nor would it be difficult for the creative person to shift to additive methods to solve certain kinds of mathematical problems even if he had been long trained to solve them by subtractive procedures. And he will be able to come up freely with new ideas even if he does know something about the type of answer expected or the method by which a solution is expected to be found.

CONTINUED ON NEXT PAGE

Creators Can Be Trained

The factors essential to the creative person are trainable, MIT Professor John E. Arnold believes. "One can, through exercise and practice," he says, "become more flexible and fluent in one's thinking."

He doesn't think talent can be created where there is none. But he does think students can be helped "to realize their creative potential to a greater degree."

In this article, Arnold details the characteristics of the creative person . . . names the steps in the creative process: to question, observe, associate, and predict. He shows clearly what creative thinking consists of . . . and the perceptual, cultural and emotional blocks which impede its operation.

Most readers will see more clearly than ever before exactly what creative thinking is and how it functions in those to whom it comes naturally. Arnold suggests, rather than describes, how people can be trained to develop it to a maximum.

Creative Engineering at MIT

At MIT, product design is used as the vehicle for demonstrating the various techniques of the creative process. There, they believe product improvement can be made in:

1. Increased function
2. Higher performance level
3. Lower cost
4. Greater salability

INCREASED FUNCTION is making a product do *more* things—or satisfying the original need by an entirely new approach.

HIGH PERFORMANCE LEVEL includes improvements resulting in longer life, greater efficiency, increased accuracy, easier maintenance, safer operation.

DESIGN FOR LOWER COST involves selection of cheaper materials and methods, elimination of unnecessary parts, design for sub-assemblies and eventual automatic manufacture.

GREATER SALABILITY includes activity associated with improved appearance, market surveys, and consumer analysis.

Dr. Arnold, who conducts this creative engineering work at MIT, voices particular amazement at the relative lack of increased-function design activity in various industries. "Group after group which I have visited," he says, "have admitted most of their 'creative activity' was toward higher performance levels—and usually at the expense of higher cost."

Other characteristics of the creative persons include:

- He is readily aware of the gaps in his environment. He can read between the lines and define the *real* problem, no matter how well it is defined. He "feels" the existence of a problem.
- He sees readily remote relationships that the non-creative person cannot see or recognize until they are pointed out to him.
- He tends to "abstract the fundamental attributes of all things learned so information obtained is easily retained and, more important, easily alterable."

But even a creative person does his best "creating" when relatively free of blocks to creative activity.

Some of these blocks are **perceptual**. Nothing can come of nothing. He who has laid up no storehouse of information about the world he lives in can produce no new combinations.

Then there are **cultural** area blocks. We're bound to be influenced by the thinking of others—living and dead. There is a block when cultural environment doesn't tolerate deviation from the traditional, when it insists on the status quo or on conformity in politics, science or at school.

Finally there are the **emotional** blocks. These include everything we inadvertently do to prevent our most productive and efficient work. It is the largest and the most devastating. The influence of our unconscious mind and our emotions on our creative work is tremendous.

Overmotivation is one important emotional block to creativity. Just plain high motivation sometimes can inhibit creativity. To maximize speed of goal attainment, overmotivation may make us take in a minimum number of clues from a given situation. We may look only for certain specific clues; let many general things pass by. Too eager to "get on with it", we may take only obvious paths; shun necessary trial and error. We may not take time to transfer from one field to another information we might well bring to bear. (The knife switch example previously noted.) . . . And, overmotivated, we may make snap judgements because we think we have more data than we actually have . . . *or become highly literal and refuse to use even the information present.*

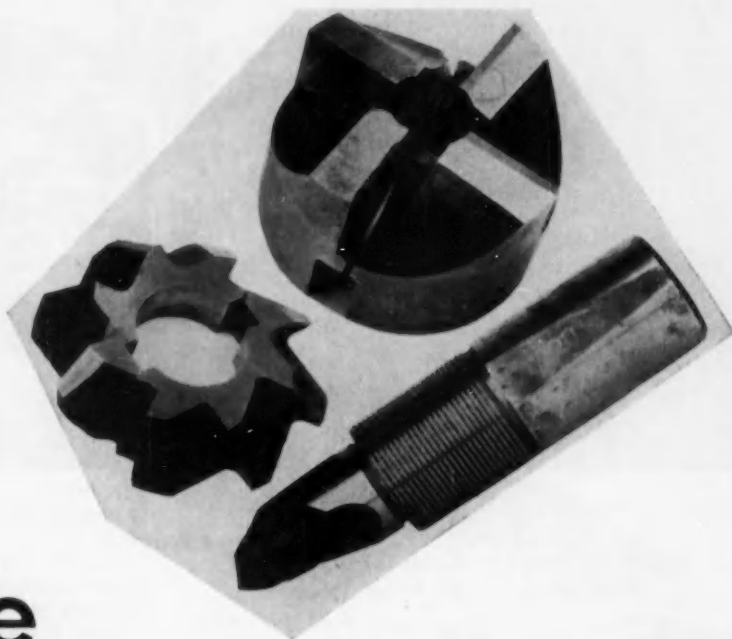
Dr. Farnsworth Sums Up

Dr. Dana Farnsworth, formerly head of MIT's medical department, sums up well when he says:

"The creative thinker (or one who is trying to be a creative thinker) is one who can go back into the well springs of his own existence, who can understand himself, see what his motives are, who can accept himself for what he is, who can recognize when he is becoming fearful, angry, jealous, suspicious . . . and then direct all his energies over into the daring side of things. When he has learned that technique, then he is in a position to learn to be creative."

(Paper on which this article is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Devotion to Detail Assures Good Tool Life



S. R. Prance, Inland Mfg. Division, CMC

Excerpts from paper, "A Sound Approach to Good Tool Life," presented at the SAE Golden Anniversary Production Meeting, Cincinnati, March 15, 1955.

TO get good tool life isn't easy. It requires a devotion to detail by all those concerned—tool engineer, tool designer, metallurgist, toolmaker, and heat-treater. Some of the spots where they may go wrong are:

1. Hardness and microstructure of the material being machined.
2. Selection of tool material.
3. Decarburization (size).
4. Stress relieving after rough machining.
5. Hardening (temperature and decarburization).
6. Quenching.
7. Tempering.
8. Grinding.
9. Stress relieving after grinding.

Tips on each of these factors will be given briefly, additional information on these and other factors important in attaining good tool life can be found in the "SAE Recommended Practice on Tool and Die Steels" (printed in full in the 1955 SAE Handbook on pp. 191-198).

Hardness and Microstructure

In cutting operations, tool life and part production may be greatly affected by the machinability of the

part material. To obtain good machinability on alloy steels, grain structure and hardness must be controlled. Fig. 1 represents results obtained with two methods of annealing alloy-steel forgings.

The effect of grain structures on the machinability of alloy steels is depicted in Table 1. This table shows the importance of annealing alloy steels under controlled conditions to obtain the most desirable grain structure for a particular machining operation.

In the medium carbon range, alloy steels having a spheroidized grain structure would give results for turning, but if it were necessary to drill and broach in addition to turn, then a lamellar grain structure would be more desirable.

In many cases it may be more economical to heat-treat the alloy steel to a sorbitic structure before machining. This is especially true on parts having dimensional requirements that would be practically impossible to maintain by heat-treating after machining and where the specified heat-treat hardness range will give at least fair machinability.

Material

The selection of a tool material for a given application is aided by considering the classification, identification, chemical composition, and metallurgical characteristics of these materials.

The SAE method of classifying tool and die steels

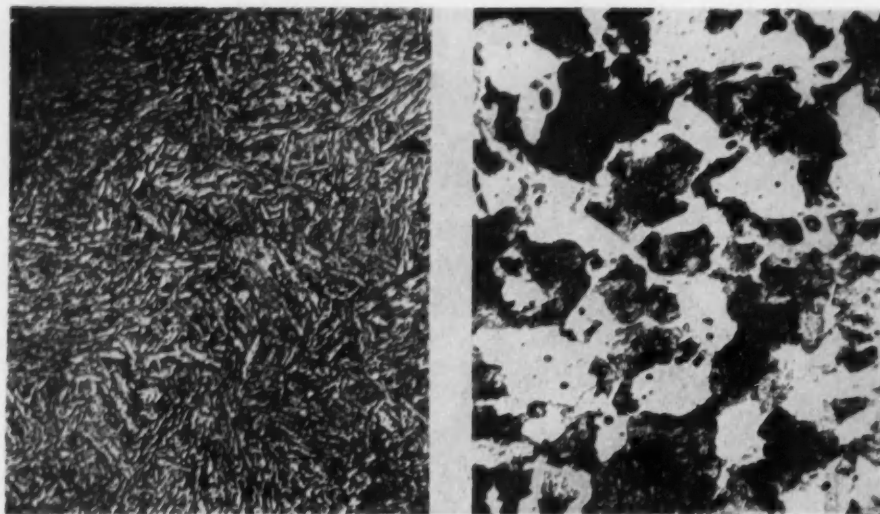


Fig. 1—Machinability of 4140 resulfurized steel forgings from same heat, but annealed by two different methods (after annealing they were of same hardness—180 Brinell). Left: subcritical annealing at 1325 F gives poor machinability. Right: full anneal at 1625 F gives good machinability

To anneal for good machinability it is necessary to control hardness and microstructure. It is readily noticed that the microstructures are radically different, which greatly affected machinability for drilling, broaching, and milling. In addition, tool life was also increased (reduced from photomicrographs taken at 500X)

Table 1—Effect of Grain Structures on Machinability of Alloy Steels

Carbon Range	Process	Structure	Turn- ing	Form- ing	Drill- ing	Broach- ing
Low (C 0.08 to 0.30)	Normalize or anneal	Blocky ferrite	Good	Good	Good	Good
Medium (C 0.30 to 0.50)	Anneal	Spheroidized	Good	Poor	Fair	Poor
Medium (C 0.30 to 0.50)	Anneal	Lamellar	Fair	Good	Good	Good
Medium (C 0.30 to 0.50)	Heat-treat	Sorbitic	Fair	Fair	Fair	Fair
High (C 0.50 to 0.80)	Anneal	Spheroidized	Good	Good	Good	Fair
High (C 0.50 to 0.80)	Anneal	Lamellar	Fair	Poor	Poor	Poor
High (C 0.50 to 0.80)	Heat-treat	Sorbitic	Good	Fair	Good	Good

Table 2—Tool Steels (Chemistry as compared to production steel 1010)

	C	Mn	Si	Cr	V	W	Mo
1010	0.10	0.45					
W1	1.00	0.25	0.25				
W2	1.00	0.25	0.25		0.25		
S1	0.50	0.25	0.35	1.40	0.20	2.25	
O1	0.90	1.20	0.25	0.50		0.50	
A2	1.00	0.60	0.25	5.25			1.10
D2	1.50	0.40	0.40	12.00			0.90
D3	2.15	0.35	0.35	12.00			
H11	0.35	0.30	1.00	5.00	0.40		1.50
H21	0.32	0.30	0.20	3.25	0.40	9.00	
T1	0.70	0.30	0.30	4.10	1.10	18.00	
M2	0.83	0.30	0.30	4.10	1.90	6.25	5.00

is given on pp. 191 and 193 of the 1955 SAE Handbook.

The first symbol in this classification is a letter which indicates the class of the steel, such as "S" meaning shock-resisting tool steels. The second symbol, a number, serves as a means of identification to differentiate each steel of a given class from others in the same classification.

The typical chemical compositions of some commonly used SAE tool steels as compared to the typical chemical composition of production steel SAE 1010 is shown in Table 2. All of the tool steels in this table contain carbon, manganese and silicon, and, with the exception of tool steel W1, one or more of the alloying elements chromium, vanadium, tungsten, and molybdenum. These alloying elements were added to produce special properties.

Chromium increases hardenability, and when a high chromium content is coupled with a high carbon content (tool steels D2 and D3) the resistance to abrasion is greatly improved.

Vanadium promotes fine-grain structures, thereby increasing toughness (tool steel W2), and with tungsten and/or molybdenum (tool steels T1 and M2) forms heat- and abrasion-resisting particles.

Tungsten increases wear by forming hard abrasion-resisting particles (tool steels S1 and O1). Tungsten also promotes red hardness and strength at elevated temperatures (tool steels H21, T1 and M2).

Molybdenum promotes air-hardening characteristics (tool steels A2 and D2). Molybdenum also promotes hardness and strength at elevated temperatures and forms hard abrasion-resistant particles (tool steels H11 and M2).

The properties and heat-treatment of carbon tool steel may, therefore, be modified considerably by the effective use of alloying elements. Adding these alloying elements alone or in various combinations to plain carbon tool steel results in:

1. Greater strength in large sections.
2. Higher toughness at the same hardness.
3. Increased abrasion resistance at the same hardness.

4. Less distortion during heat-treatment.

5. Greater hardness and strength at elevated temperatures.

Hardness, strength, toughness, wear resistance, and resistance to heat softening are, therefore, prime selective factors for tool steel applications. Many other properties must be seriously considered in individual applications; these include permissible distortion in hardening, permissible surface decarburization, hardenability or depth of hardness desired, resistance to heat checking, machinability and grindability, as well as heat-treating requirements, including temperatures and atmospheres, and equipment.

The SAE has evaluated tool steels on a metallurgical basis for those properties which merit special consideration when selecting a tool steel for any application. For convenience, Fig. 2 was developed by transposing the 1955 SAE ratings to an approximate numerical value on four properties for each class of tool steel. The four properties are minimum distortion, shock resistance, heat resistance, and abrasion resistance. The properties involved when rating for the ability to cut are hardness, heat resistance, and abrasion resistance.

This diagram gives comparative ratings and may be used as an approximate guide to the selection of a class of tool steels for various applications. In many cases there is an advantage of one tool steel over another tool steel in the same class.

If a tool is subjected to impact, then the tool material should be selected from the class of shock-resisting tool steels. Similarly, if it is to be used at elevated temperatures, it should be chosen from the class of hot-work tool steels.

A tool steel from the "O" class of cold-work tool steels would be a satisfactory choice for a cold-work blanking die having a nonuniform shape and re-

quiring good production life because, for this application minimum distortion, abrasion resistance, and some toughness are the prime selective factors. For the same application, the "A" class of cold-work tool steels would have less distortion, somewhat longer production life, while still maintaining approximately the same degree of toughness. Also, for the same application a longer production life at some sacrifice in toughness may be had by using a tool steel from the "D" class of cold-work tool steels instead of the "A" class.

In general, most cutting tools for continuous high-speed production should be made from the "T" and "M" class of high-speed tool steels or sintered carbides.

The water-hardening class of tool steels is easy to machine, and because they are usually water-quenched warpage may be expected. Therefore, they should only be considered for tools having uni-

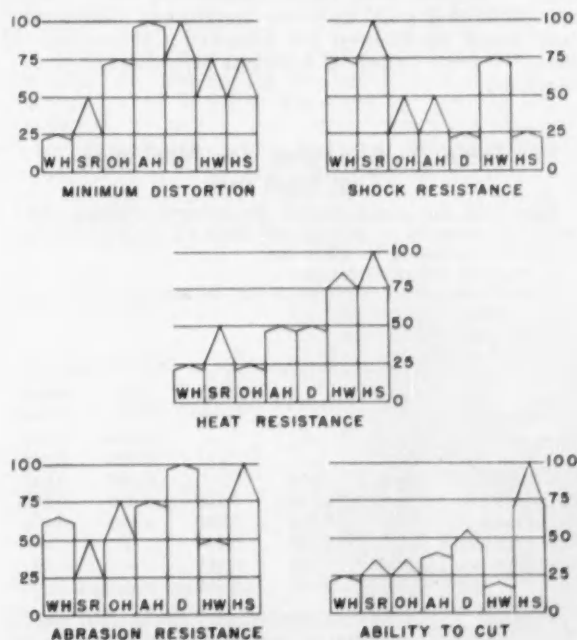


Fig. 2—Metallurgical evaluation of tool steel

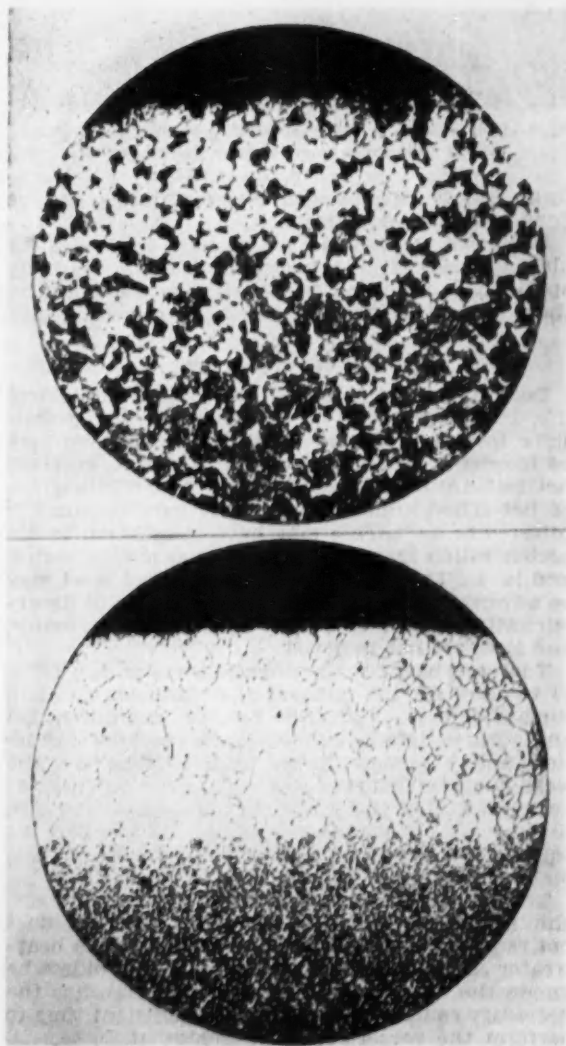


Fig. 3—Upper view: partial decarburization. Lower view: total decarburization (reduced from photomicrographs taken at 100X)

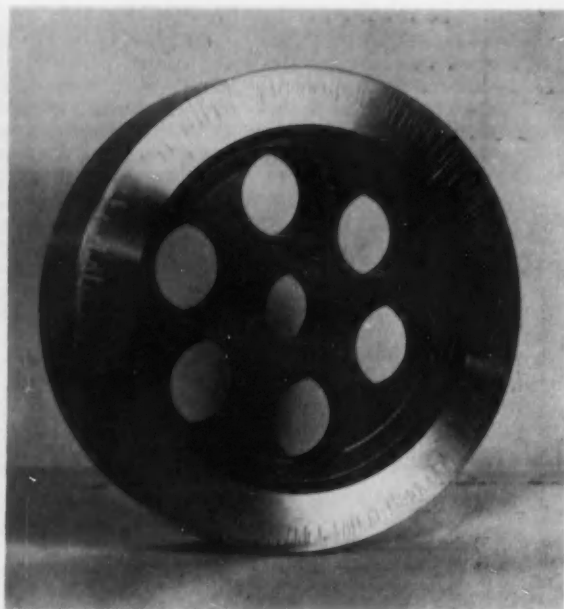


Fig. 4—Surface cracks in plug gage, resulting from too severe grinding. Cracks made visible by wet magnetic particle method

form, sturdy designs and where grinding can be done after heat-treatment.

Final cost per unit part produced by the tool is the ultimate basis of proper selection. There are many applications requiring special consideration, and in these cases it is advisable to consult a metallurgist.

Decarburization

Decarburization, one of the worst enemies of tool life, is shown in Fig. 3. These photomicrographs show total and partial decarburization which may be frequently present on the surface of as-received hot-rolled and annealed tool steel bars. The surface of hot-rolled annealed tool steel bars (commonly referred to as "bark") may have in addition to decarburization such surface defects as slivers, seams, and laps. The serviceability of any tool steel may be adversely affected even in the absence of decarburization if surface defects such as slivers, seams, and laps, are not removed.

Tool steel bars must be ordered oversize (see Table 3) to allow for the removal of decarburization and surface defects. Failure to remove decarburization and surface defects may result in excessive distortion and breakage during heat-treatment. The wear characteristics of any tool or die will be adversely affected if decarburization is not removed. Remove an adequate amount and, if possible, an equal amount from all sides of tool steel stock when making a tool or die.

The advantages of good design, selection, and machining can be a complete loss if the tool does not receive the correct heat-treatment. The heat-treater cannot heat-treat a tool correctly unless he knows the chemistry of the tool material, has the necessary equipment, and is given sufficient time to perform the prescribed heat-treatment.

It is not the intent of this article to cover details for heat-treating the various tool steels. Recom-

mended heat-treatments for SAE tool steels are listed on p. 194 of the 1955 SAE Handbook. Presented below are some heat-treat precautions.

Stress Relieving and Hardening

Stress relieving at 1100 to 1200 F after rough machining and before finish machining and hardening is often advantageous in minimizing dimensional change during heat-treatment.

Proper supports must be provided for the tools to avoid sagging in the hardening furnace. Steels are very weak especially at and above their hardening temperatures and will sag or flow plastically unless properly supported.

If it is necessary to design tools with sharp corners, thin sections, and bolt holes and if such areas do not require high hardnesses, it would then be desirable to pack these areas with asbestos or fire clay before hardening.

In heating for hardening, use controlled atmosphere furnaces, neutral salt baths, or molten lead baths to avoid decarburization. Decarburization, grain growth, and increased hazards of cracking in quenching may result if temperatures for hardening are higher than recommended or if the holding time at the proper temperature is excessive.

Quenching and Tempering

For uniform results during water or oil quenching, sufficient coolant is necessary to maintain the quenching medium at the proper temperature. Tools should be agitated during quenching to minimize gas pocketing. For tools that require an air quench, use still atmospheric air at room temperature. During air quenching, the tools should be held or supported so as to allow uniform cooling.

Tools should always be tempered immediately after reaching 100-150 F in the quenching operation. Tempering to lower hardnesses than those recommended may decrease toughness. Adequate time must be allowed for tempering if maximum benefits from relief of internal stresses are to be obtained.

Table 3—Allowance for Machining Tool Steel Bars

Tool and die steels should be ordered oversize, with sufficient material to be removed from all surfaces by machining or grinding to allow for:

- Surface decarburization.
- Surface defects, such as slivers, seams, laps, and scale marks.
- Undersize tolerance.

Minimum Allowance on One Side, in.

Size, in.	Hot Rolled	Hammered	Rough Turned	Cold Drawn	Rough Ground
To 1/2 incl.	0.020	—	—	0.020	0.005
Over 1/2 to 1 incl.	0.040	—	—	0.040	0.010
Over 1 to 2 incl.	0.060	0.090	—	0.060	0.015
Over 2 to 3 incl.	0.080	0.120	0.025	0.080	0.020
Over 3 to 4 incl.	0.100	0.150	0.030	0.100	0.025
Over 4 to 6 incl.	0.187	0.190	0.045	—	—
Over 6 to 8 incl.	0.250	0.250	0.060	—	—
Over 8	—	0.250	0.090	—	—

Polished or ground tool-steel-quality round drill rod is free from decarburization or any surface defects requiring surface removal.

The following tempering times at temperature should be used:

300 F	4 hr/in. max cross-section
400 F	2 hr/in. max cross-section
600 F or higher	1 hr/in. max cross-section

Multiple tempering of all hardened tool steels will give the best properties. Double tempering or triple tempering is essential for all air hardening, hot work, and high-speed tool steels, due to the fact that they retain a considerable percentage of austenite after quenching. Multiple tempering is started immediately after quenching when the tool steel reaches a temperature of 100-150 F. The first tempering affects the martensite formed in the quench and conditions the remaining austenite so that it transforms to martensite upon aircooling to room temperature. The second tempering operation is necessary to affect the martensite which forms after the first temper. The above completes a double tempering operation. For the third tempering operation, cool to room temperature and repeat.

Grinding and Stress Relieving

There are several ways in which a ground surface may be injured. It may be cracked, it may be highly stressed, or it may be burned. These effects are injurious only if the useful life of the tool in the service to which it is subjected is affected adversely. Cracks and stresses in ground surfaces are generally considered harmful since they are likely to grow under service conditions until the tool breaks.

Burn marks in steel are an indication that relatively high surface temperatures have been momentarily reached in grinding. Burns may be visible as a discoloration of the surface, but its effect may still be present even if the burn color is removed. In hardened steels, burn may result in softening, which is definitely injurious if it is present in the cutting edge of a tool, or it may result in rehardening which leaves the surface in a brittle condition.

In many instances, these surface injuries can be eliminated by decreasing the severity of grinding by changing to a softer wheel or by feeding less rapidly.

Tools that crack readily during or after grinding are often said to be sensitive to grinding. This condition is frequently due to improper heat-treatment. For example, if the tool is not tempered and/or not sufficiently tempered after hardening, it contains

untempered martensite, which is brittle and easily cracked during grinding.

Hardened steels are also likely to crack in grinding if they contain an appreciable amount of retained austenite. This is because retained austenite is unstable and during grinding may transform into martensite. Elimination of retained austenite by suitable tempering has been found to make hardened steel much easier to grind without cracking.

If decarburization has not been completely removed by machining prior to hardening or if it occurs during hardening, a grinding wheel that has been properly selected for grinding hardened steel may start loading while in contact with the soft decarburized layer. Then when the loaded wheel does come in contact with the hard steel, it is likely to burn the work and may even crack it.

The surface cracks in Fig. 4 were made visible by the wet magnetic particle method. Although cracks in hardened steel can be detected by acid etching, the magnetic particle method is preferred because it is nondestructive.

The surface burn condition in Fig. 5 was made visible by a special etchant. This etchant has no harmful effect upon the tool from the standpoint of its useful life and actual service. This piece of hardened tool steel was severely ground so that it was badly burned. One end was then shimmed up 0.015 in. and the burned surface was ground on a taper, very gently, with a soft wheel, until 0.015 in. was removed at the raised end of the piece (which is at the right in the photograph) and nothing at the opposite end. All signs of burn were removed in this manner. The tool steel was then etched with the above special etchant, which brought out the pattern of white and dark areas at the location that was not shimmed.

The ground surface of a hardened tool may be highly stressed after grinding but not cracked. These high stresses may develop cracks immediately after grinding, before use or during use. In such cases it is often possible to salvage the tool by stress relieving immediately after grinding at or just below the tempering temperature in order to maintain the specified tool hardness.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

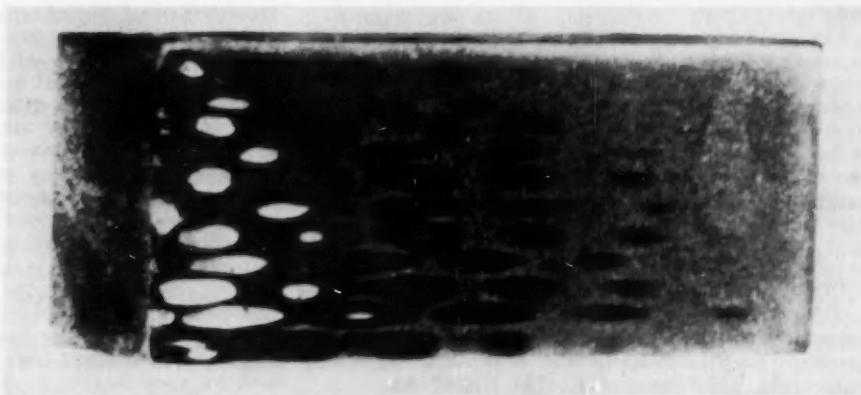
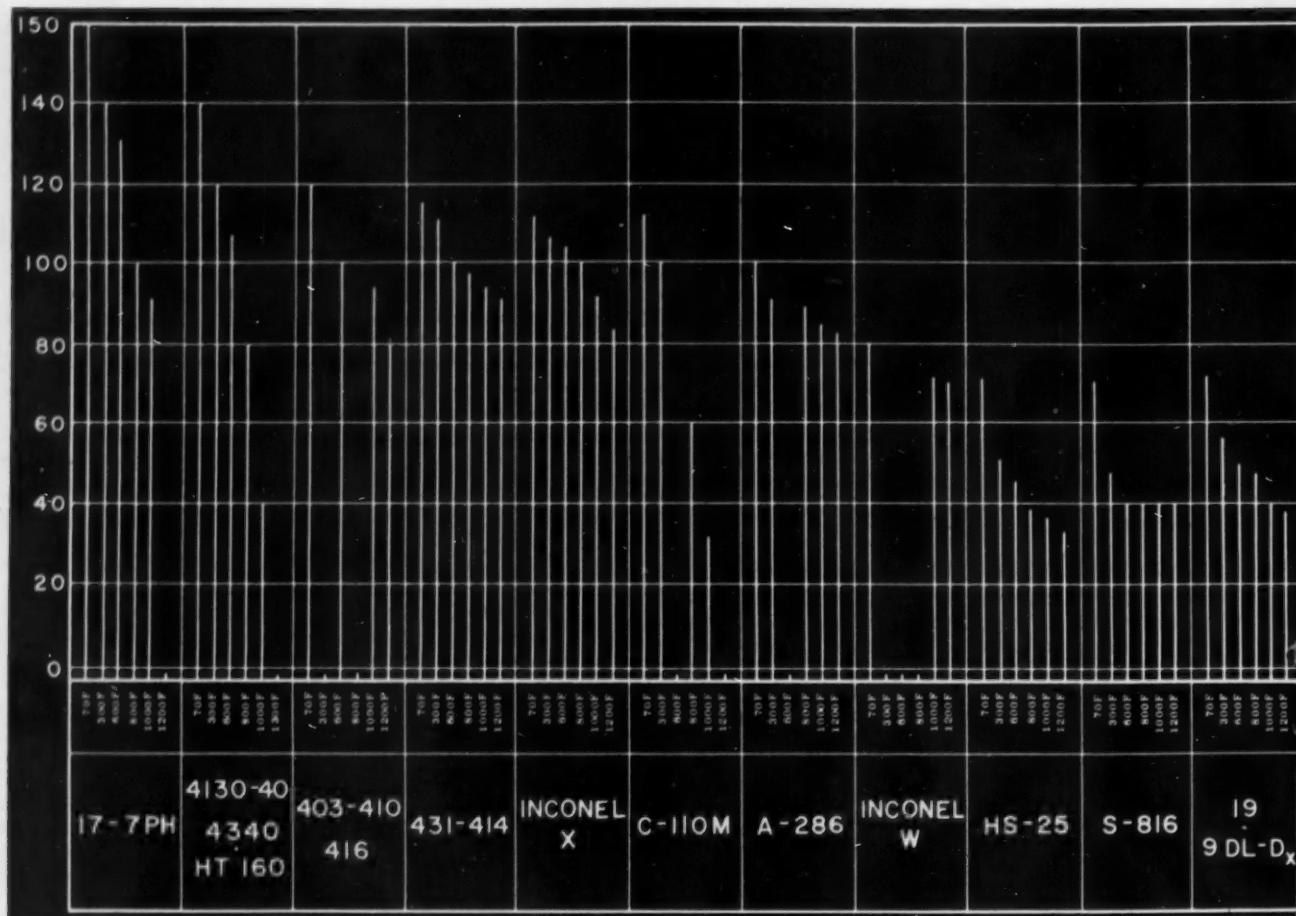


Fig. 5—Hardened tool steel that was severely burned in grinding, showing rehardened white areas, softened black areas, and unaffected gray areas



Part II - Metals

H EAT from aircraft powerplants and from aerodynamic friction at supersonic speeds changes the properties of metals used in the aircraft. The changes depend upon the temperature, the duration of the exposure to the heat, the composition of the metal alloy and its properties, and the use to which the metal is put.

The strength of metals generally decreases with increasing temperatures. Age-hardenable materials over-age, thereby losing strength. Work-hardened materials anneal themselves. Materials containing many different alloying elements form new phases at high temperatures and can lose strength or become brittle. Also, the atomic bonding that holds metals together and gives them strength changes when subjected to additional heat energy and by

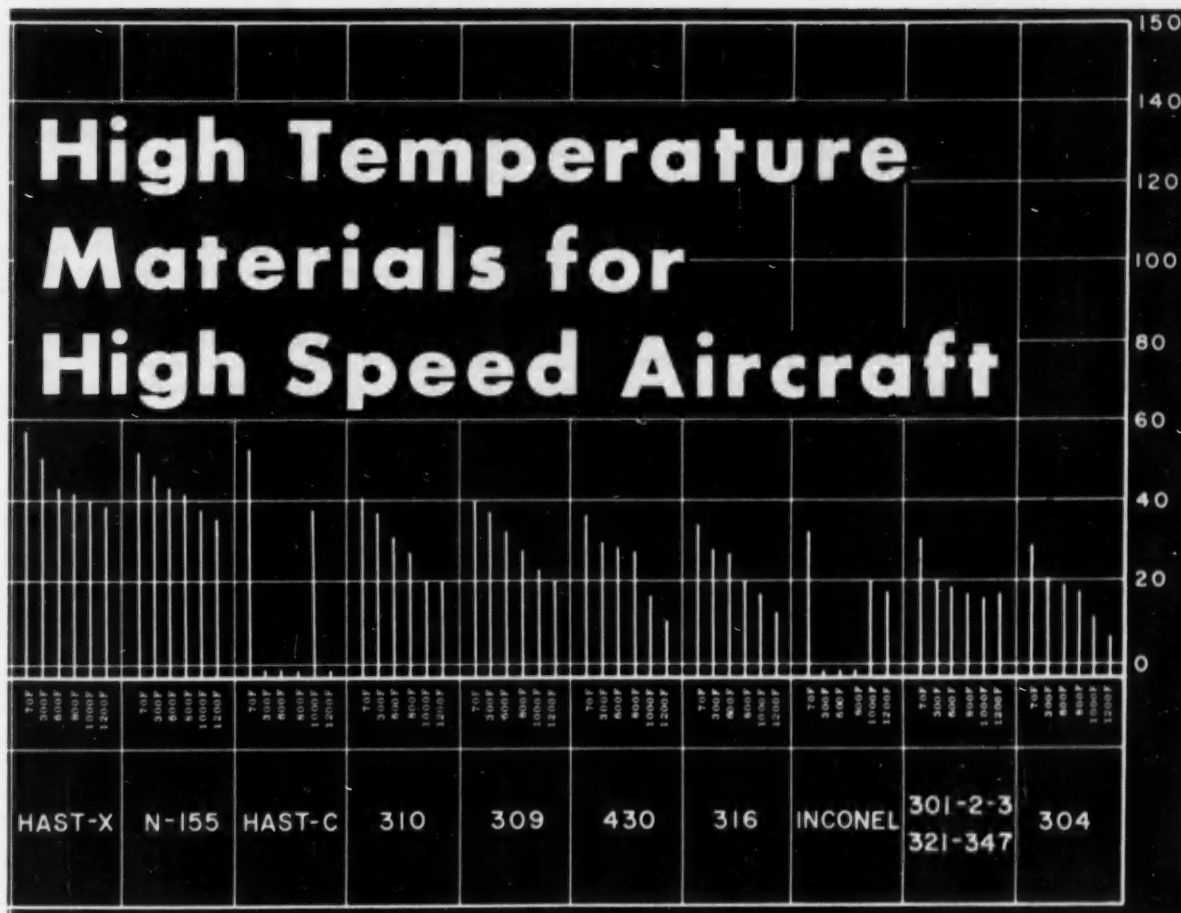
various mechanisms reduces the strength of the alloy.

Because metals lose strength at high temperatures, the service temperature and life of the airplane part must be carefully considered before the material is chosen. The various measurements of strength must be integrated to prevent a material good in one strength property being selected for an application where a high temperature peculiarity of the metal will result in failure. Some metals have comparatively high short-time strength, but considerably lower creep strength than others. Some metals have hot-short or brittle ranges at certain temperatures. Others precipitate constituents in grain boundaries at certain temperatures that severely reduce their performance under load.

Unfortunately, alloys with desirable properties in one temperature range may be completely unsuitable at other temperatures. So until a material is discovered that is able to withstand temperatures from way below zero to several thousand degrees above zero, aircraft manufacturers must select alloys for specific uses in specific temperature ranges.

This is Part II of a two-part article on high temperature materials used to break through the heat barrier. Part I—Nonmetallic Materials—appeared in the July, 1955 issue of the SAE JOURNAL.

High Temperature Materials for High Speed Aircraft



THERMAL LIMITATIONS OF MATERIALS AT HIGH TEMPERATURES (0.2% Yield Strength)

Three temperature ranges (1) up to 600 F, (2) 600-1100 F, and (3) 1100-2400 F, will be discussed separately.

Metals to 600 F

In addition to lightness and strength, which traditionally have been the properties desired in aircraft materials, heat resistance is becoming increasingly important. This requirement can be illustrated by noting that as temperatures are increased from room temperatures to 600 F common alloys lose their strength.

Fig. 1 shows the drop in tensile strength of the more common heat-treatable aluminum alloys: clad XA78S-T6 (X7178), clad 75S-T6 (7075-T6), clad 24S-T81 (2024-T81) and clad 61S-T6 (6061-T6). The change in tensile properties of two magnesium alloys AZ31 and a new zirconium-thorium-magnesium alloy HK31X-T6, and of an aluminum-aluminum oxide powdered sintered material M-257 (approximately 7.5% oxide) are shown also. The HK31X-T6 and M-257 have relatively good properties in the higher temperature ranges.

Of course other metals have been proposed and are being used at temperatures above the ceiling recommended for the aluminum alloys. A comparison of these materials on a strength-weight basis plus three of the materials shown in Fig. 1 has been made in Fig. 2. The titanium alloys, the precipitation hardening steels such as 17-7PH, and the normal aircraft steel alloys heat-treated to high strength levels, offer a better hope for obtaining the lightest structures than either the aluminum alloys, the zirconium-thorium-magnesium alloys, or the new sintered aluminum products. The data reported in Figs. 1 and 2 are based on exposure times of approximately 1/2 hr prior to testing. At extremely rapid heating rates the properties would be considerably higher.

On the other hand, extended exposure times will cause a drop in the high-temperature properties of wrought aluminum alloys. For example, aged 24S loses 25% of its ultimate tensile strength after 1000 hr exposure at 300 F and it loses over 50% after 1000 hr at 600 F.

Extended exposure times up to 1000 hr do not

greatly affect the mechanical properties of zirconium-thorium-magnesium alloys until temperatures near 600 F are reached. Over 600 F however, this alloy loses over 50% of its ultimate tensile strength and approximately 75% of its tensile-yield strength in 1000 hr.

Sintered aluminum powder products do not exhibit any change in properties with increased exposure times.

Annealed commercially pure titanium exhibits only slight changes in mechanical properties with exposure times of 1000 hr.

The only titanium alloy about which there is any extensive data is the 8% manganese sheet alloy. At 300 F this alloy exhibits softening and then hardening characteristics. Between 500 and 600 F, aging begins immediately and reaches a maximum in ap-

proximately 100 hr, as shown by the increase in tensile properties. Overaging or softening then begins and at the end of approximately 1000 hr, the tensile strength of the overaged 8% manganese titanium alloy is approximately the same as the high temperature properties of the annealed material tested after only a short exposure time.

Cold-worked stainless steels show slight aging tendencies with corresponding slight increases in the ultimate tensile strength. However, the major portion of the available data is only for 100-hr exposure time. The effect of exposure times over 100 hr on the cold-worked stainless steels remains to be determined.

The effect of *continuous* exposure time on the mechanical properties of heat-treated steels is not yet completely understood. It has long been felt that temperatures under the tempering temperatures would not produce any significant change in mechanical properties. However, some tests on SAE 8630 steel indicate that at 400 and 600 F an increase in strength occurs up to 10 hr exposure and some softening occurs between 10 and 100 hr, so further experimentation is necessary.

Based on the absence of any structural changes or precipitants in 17-7PH below 600 F, it seems that extended exposure in this range will not affect the high temperature material properties.

Structural failure can also occur at room temperatures after certain materials have been exposed to extremely high temperatures. Aluminum and magnesium alloys suffer permanent losses in room-temperature properties if the exposure temperatures and times deviate from a rather narrow range. Safe times and temperatures for these two materials are similar to those used in hot-forming shops.

For other metals the available data is very limited. Since 17-7PH does not undergo any microstructural changes below 600 F, the room temperature properties will not be affected. Annealed commercially pure titanium and stainless steels, even the cold-worked steels, similarly remain unaffected. There is some indication that titanium alloys or heat-treated alloy steels do undergo microstructural changes, however.

Metals 600 to 1100 F

In recent months there has been an upsurge in the efforts of research organizations to obtain data about the properties of metals that are most useful for airframe structures from 600 to 1100 F. For convenience, we can classify them into the following four types: (chemical composition is listed in Table I)

1. Martensitic steels
2. Austenitic steels
3. Precipitation hardening alloys
4. Titanium alloys

Martensitic steels can be heat-treated to very high short-time strengths. They are unstable under prolonged heating, and have relatively poor corrosion resistance. The austenitic steels generally have relatively low short-time strength. They are unresponsive to heat-treatment, and are stable under prolonged heating, except that some types exhibit a microstructural instability at certain temperatures that leads to serious corrosion effects. Otherwise, the austenitic steels are very corrosion resistant.

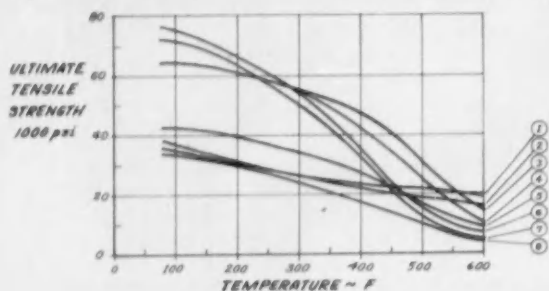


Fig. 1—High temperatures decrease the ultimate tensile strength of various alloys. (1) HK31XA-T6 zirconium-magnesium-thorium alloy (2) M257 APMP (3) Clad 24S-T81 (4) Clad 14S-T6 (5) Clad 61S-T6 (6) Clad X7178-T6 (7) Clad 75S-T6 (8) AZ31 magnesium alloy.

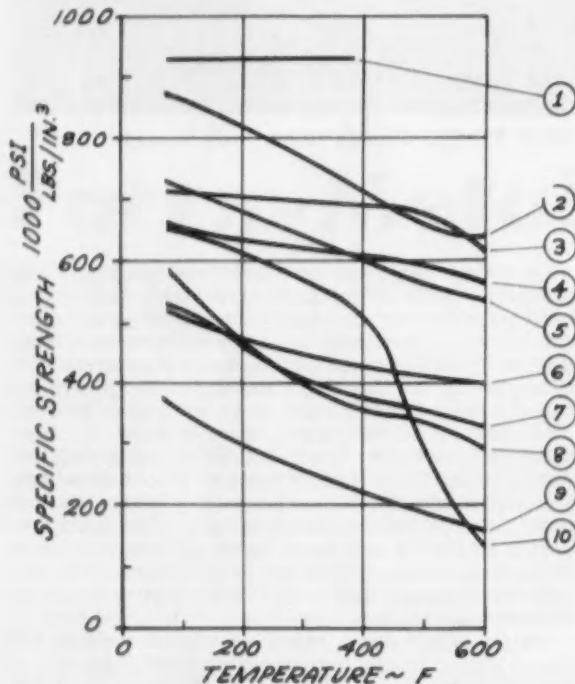


Fig. 2—Tensile-strength weight ratios of alloys at high temperatures (1) SAE 4340—260,000-280,000 psi (2) 4 Al-4 MN Ti (3) SAE 4340—200,000 psi (4) 17-7 PH-THD 1050 (5) Ti alloy sheet (6) ½ H CRES. (7) Chemically pure Ti (8) HK 31 XA-T6 (9) M257 APMP (10) Clad 24S-T81.

Table 1—Composition of Metal Alloys (600-1100 F) by Per Cent

Alloy	C	Cr	Ni	W	Mo	Ti	Al	Fe	Others
Type 1									
(Martensitic)									
4130	0.30	0.95	—	—	0.20	—	—	Bal	—
4340	0.40	0.8	1.8	—	0.25	—	—	Bal	—
422	0.20	13.00	0.75	1.05	1.05	—	—	Bal	V, 0.25
HWD*	0.33	5.00	—	1.25	1.45	—	—	Bal	Si, 0.85; V, 0.23
AMS 5616	0.15	13.00	2.00	3.00	—	—	—	Bal	—
Type 2									
(Austenitic)									
301	0.15	17.00	7.00	—	—	—	—	Bal	—
321	—	18.00	10.00	—	—	0.50	—	Bal	—
19-9DX	0.30	19.00	9.00	—	1.50	0.60	—	Bal	—
Type 3									
(Precipitation Hardening alloys)									
17-7PH	—	17.00	7.00	—	—	—	1.15	Bal	—
A286	—	15.00	25.00	—	1.25	2.10	0.35	Bal	V, 0.25
Inconel X	—	15.00	Bal	—	—	2.30	1.20	7.00	Cb, 1.00
Type 4									
(Titanium alloy)									
AMS 4908	—	—	—	—	—	Bal	—	—	Mn, 8.00

* A hot work die steel

The precipitation hardening alloys have high strength properties. They are generally stable under prolonged heating, and are very corrosion resistant. The titanium alloys are much lighter in weight than the other alloys discussed and have high strength in proportion to their weight.

Short time tensile properties

In Fig. 3 are compared the tensile ultimate strengths at elevated temperatures of several of the alloys following a short exposure at each temperature. The values in parentheses in this and in succeeding figures are the tensile ultimate strengths at room temperature. Generally, those alloys whose curves fall away rapidly with increasing temperatures, such as some martensitic steels and 17-7PH, are relatively unstable at the higher temperatures. Also their creep strengths may be relatively low at higher temperatures. A flat curve, such as obtained from the precipitation hardening alloys and the austenitic alloys, indicates stability and good long-time properties at the higher temperatures.

Additions of tungsten and molybdenum to martensitic steels improve the ultimate strength, particularly at the higher temperatures. The high carbon content of the hot work die steel as compared with the 422 martensitic permits very high strengths to be reached.

To compare the titanium-manganese alloy with the heavier alloys on a strength/weight basis, the values for the titanium must be increased by a factor of approximately 1.7. The tensile ultimate values for the titanium alloy multiplied by 1.7 and plotted in Fig. 3 would form a curve lying just above the 17-7PH curve at 600 F and slightly below the 4340 at 900 F.

The tensile yield strengths are shown in Fig. 4. The yield strength is used less frequently than the ultimate for design purposes. When the yield is less than two-thirds of the ultimate, the yield may be the limiting factor since it is required that aircraft structures do not permanently deform at the highest stress expected in service. The yield curve

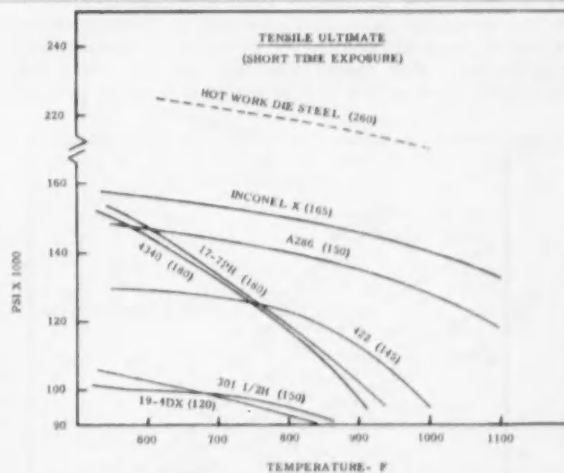


Fig. 3—Ultimate tensile strength of various alloys following a short exposure at each temperature. Values in parentheses are the tensile ultimate strengths at room temperature.

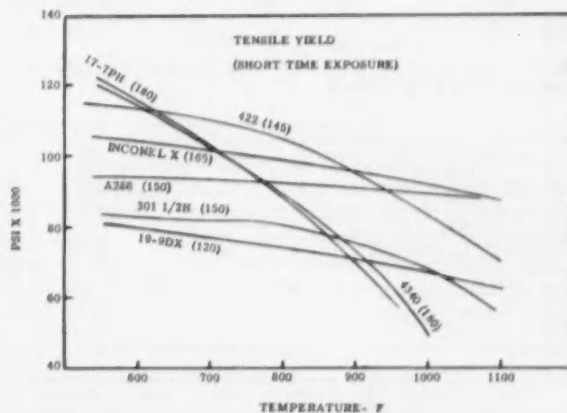


Fig. 4—Tensile yield strengths of various alloys. Note in comparing with Fig. 3 that the martensitic steels have much higher relative strength at the lower temperatures on the basis of tensile yield.

of the titanium-manganese alloy multiplied by 1.7 if plotted in Fig. 4 would lie almost on the 4340 curve from 600 to 900 F.

Effects of prolonged heating

Figs. 3 and 4 present a useful comparison of the short-time properties of the alloys only if exposure to heat has been short. Throughout a certain temperature range, which is characteristic for each alloy, the properties are maintained during very long exposure. At higher temperatures the strengths decrease as a function of time.

In Fig. 5 are shown curves for tensile ultimate versus temperature for SAE 4340 at several heat-treat levels. Above a certain temperature an exposure of 1000 hr appreciably lowers the strength. The curves are drawn to indicate roughly the lowering that would be detected in a test conducted at a given temperature if the metal were exposed for 1000 hr.

Fig. 6 shows for a number of alloys the temperature ranges in which tensile ultimate is maintained for 1000 hr. At temperatures considerably below those affecting the strength, the micro-structure of the unstabilized 18 Cr-8Ni type steels is altered in such a manner that very damaging intergranular corrosion may subsequently develop in certain environments. For materials that are heat-treated, the upper limit of the stable range is usually related

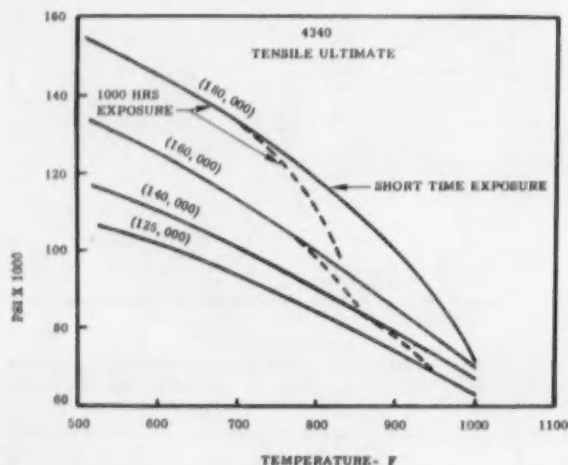


Fig. 5—Above a certain temperature prolonged exposure (1000 hr) appreciably lowers the strength.

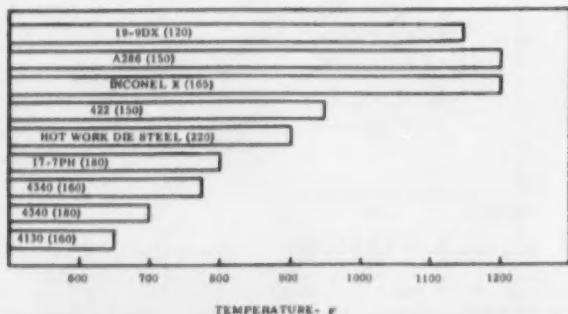


Fig. 6—Temperature ranges in which tensile ultimate strength is maintained for 1000 hr.

to the heat-treat temperature. For the low-alloy steels, of which 4340 may be considered typical, the upper limit for stability for about 1000 hr will be about 150 to 200 F below the tempering temperature. The ductility of an alloy may be adversely affected by prolonged heating within the temperature range where the tensile strength is maintained in smooth test specimens. The loss of ductility may be reflected in an increase in notch sensitivity. Practically, this means that the strength may be lowered in a part where a stress concentration exists.

Short-time compression, shear, and bearing stresses

Shear and bearing ultimates for a few alloys are expressed in Figs. 7 and 8 as a fraction of the corresponding elevated temperature tensile ultimate strengths. Such curves can be used to predict the strengths of similar alloys for which no direct data exist.

A few tests indicate that the compression yield is close to the tensile yield except in those cases where anisotropy exists, as in work-hardened stainless steel. No data have been found on bearing yield at high temperatures.

Creep and stress rupture

The tensile stresses causing rupture in 100 hr and in 1000 hr are shown in Fig. 9. The 1000-hr rupture curve for the titanium-manganese alloy (17-7PH) multiplied by 1.7 for weight adjustment lies almost directly upon the 100-hr curve for SAE 4340.

This information given by the stress-rupture curves is valid although the temperatures may be above the stable range, since the effect of exposure is evaluated by the nature of the test. However, if much higher loads than those shown are applied momentarily, consideration must be given to the possible effect of exposure on the short-time strength. Under stress-rupture conditions the metal is exposed for long periods to both stress and heat. Generally a sufficiently accurate estimate of the effect on the metal will be obtained by considering the heat effect only, since it has been found that the effect of stress is minor in comparison.

Notch effects

In their initial conditions most metals show notch strengthening in static tests. However, prolonged

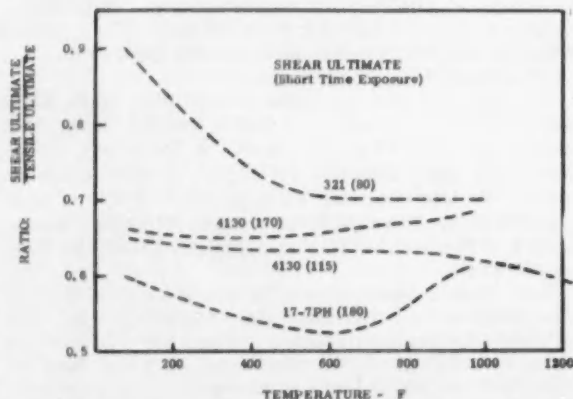


Fig. 7—Shear ultimate expressed as a fraction of the corresponding temperature tensile ultimate strengths.

exposure to heat may result in loss of ductility. This loss may proceed to the point where notches weaken the material. These principles are illustrated in stress-rupture tests on two martensitic steels as shown in Fig. 10. In short-time tests the notched specimens were stronger. After long times at low stresses, the notch no longer had a strengthening effect in SAE 4340 and became a weakening element in the highly alloyed AMS 5616 steel.

Fabrication characteristics

The final selection of a material for a particular use frequently depends as much upon fabrication characteristics as upon strength.

All of the alloys listed in Table 1 can be shaped by the ordinary machining and forming operations. The austenitic steels in general are the most readily formed of the several alloy types. Alloy 17-7PH is fully equal in formability to the austenitic steels in most respects. Alloys of the type represented by Inconel X and A286 are somewhat difficult to form. The martensitic steels are intermediate between the other two types in formability. The martensitic steels rate highest in machinability, the austenitic grades and 17-7PH are intermediate, and the two other precipitation-hardening alloys rate as the most difficult to machine.

All of these alloys can be hot worked satisfactorily. Maximum strengths cannot usually be achieved after hot working in alloys such as one-half hard 301 or 19-9DX that require certain amounts of cold or hot-cold working for strength. All of the other alloys can be heat-treated to normal strengths after hot working.

Problems arising in heat-treating or joining may be decisive factors in the selection of an alloy. Other things being equal, low heat-treat temperatures are desirable since problems arising from warping and oxidation are thereby minimized. The precipitation hardening alloys such as Inconel X and A286 require only relatively low aging temperatures for maximum properties. Dimensional changes during heat-treatment are very small for these two alloys and warping is not usually a problem. The martensitic steels require heating to higher temperatures for hardening and may change dimensionally by various amounts during hardening, de-

pending upon the size and shape of the part. Consequently, considerable trouble from warping is usually encountered in fabricating parts from these alloys. Alloy 17-7PH grows about 0.5% in all directions during its final heat-treatment, and therefore may warp considerably.

In those alloys that warp excessively, elimination or removal of warping may be accomplished by restraint during heat-treatment or by cold or hot straightening after heat-treatment. Generally, the higher the final strength of the alloy, the more difficult is the warpage to remove.

Joining by fusion welding can be satisfactorily accomplished on all of the heavy alloys discussed. Except in the austenitic steels, the welds may be heat-treated to high strengths. Welding of highly hardenable martensitic steel requires special care to prevent cracking.

Metals 1200 to 2400 F

The metals available for use in the temperature range between 1200 and 2400 F are limited by their properties of thermal expansion, heat conductivity, surface emissivity, and scaling resistance, as well as

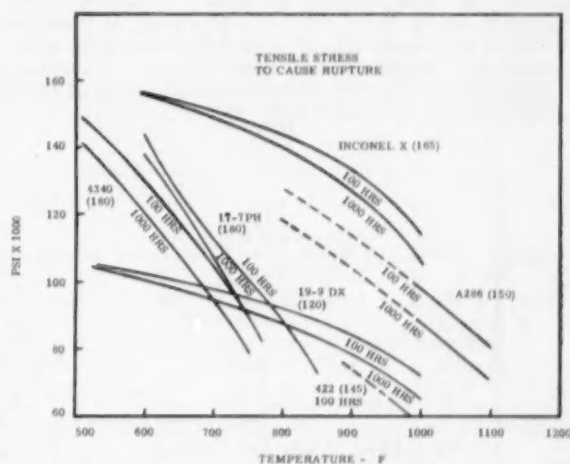


Fig. 9—Tensile stresses which cause rupture after 100 hr and 1000 hr exposure to high temperatures.

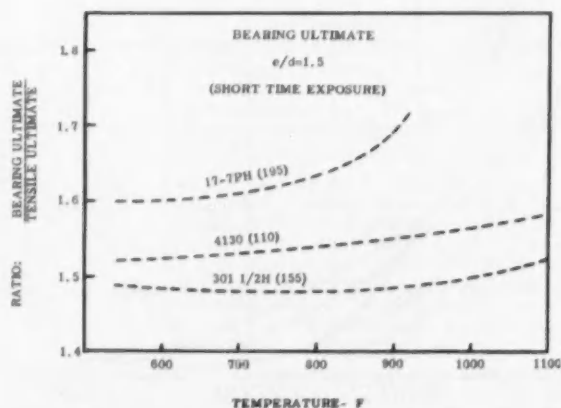


Fig. 8—Bearing ultimate expressed as a fraction of the corresponding temperature tensile ultimate strengths.

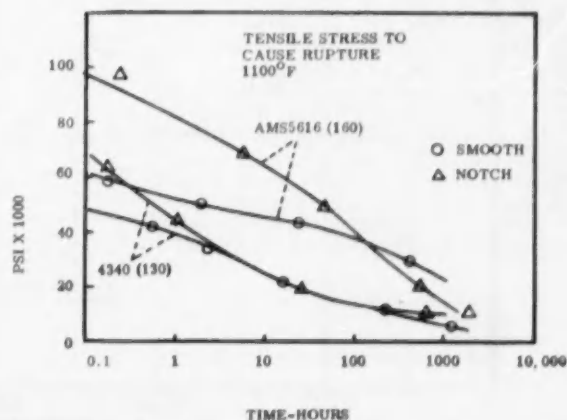


Fig. 10—At prolonged exposure to high temperatures, notches will weaken the material.

the traditional high strength/weight ratio. Particularly in the fields of turbojet afterburner, ramjet, and rocket engine design, the search for good high temperature materials goes on with increasing intensity.

The classes of metals that retain sufficient strength to be used in the service temperature range above 1200 F are the alloys which have iron, nickel, or cobalt as the major constituent. Alloys based on all three of these elements and mixtures of them are currently being used in countless powerplant applications. New developments in metals technology are preparing alloys based on molybdenum, titanium, and possibly chromium and other metals; but at this time iron, nickel, and cobalt are the foundation elements for the high temperature alloy field. Table 2 is a list of some of the commonly used alloys and an insight into their characteristics, divided into classes based on their major constituent. In general, it can be said that alloys of iron are used in the temperature range up to 1500 F, alloys of nickel in the temperature range 1500-1800 F, and alloys of cobalt in the range 1600-2200 F.

Fig. 11 shows the variation of ultimate tensile strength with temperature for several high temperature alloys. Heat-treated Inconel X is the strongest material up to about 1600 F. However, it has low ductility at about 1200 F due to a hot-short phenomenon. High-critical-alloy-content materials, L-605, and S-816 retain the greatest strength at temperatures higher than 1600 F. Other materials, com-

bining wide limits of properties, fall below these materials in strength at high temperatures. The strength level at 1800 F and up for all alloys is very low. Many of the high temperature components of afterburners and ramjet engines can be designed to function at temperatures up to 2200 F for short intervals. It is essential, however, that the strength be known at these temperatures so that compensating increased thicknesses can be used. Unfortunately, data at the high temperatures are rather limited.

In addition to mechanical properties, the physical properties of metals, such as coefficient of expansion, thermal conductivity, and emissivity become very important in high temperature service.

Thermal stresses due to differential expansion of parts subject to different temperatures or differential expansion at a joint between metals of different thermal expansion can comprise as much as 50% and higher of the total applied load on the part. Many cases of failure due to differential thermal expansion are on record. In general, a low coefficient is desired. However, equally as important, in the case of dissimilar metal joints, is an equal coefficient of thermal expansion, high or low.

Thermal conductivity becomes critical in applications such as combustion chambers where it is important that heat be rapidly distributed and dissipated. This is especially true where uneven combustion produces hot spots. Since most high temperature alloys have comparatively low thermal

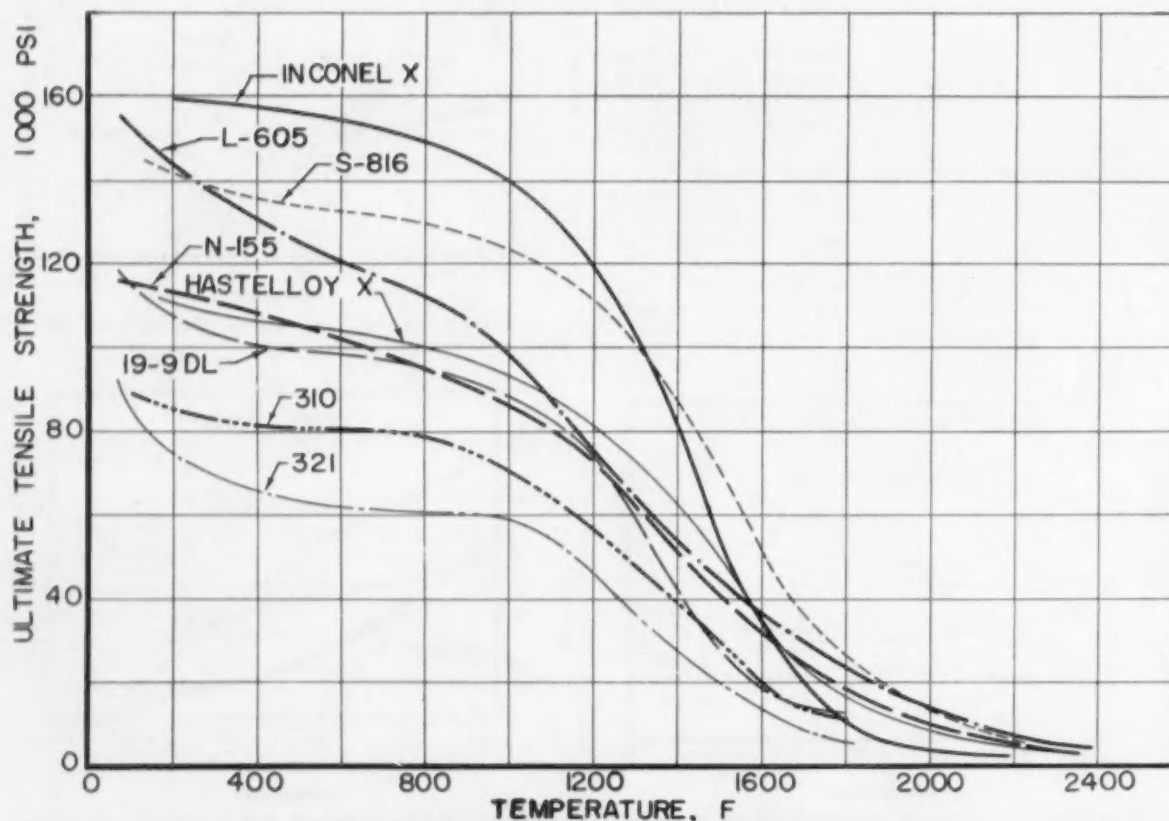


Fig. 11—Typical ultimate tensile strength for high temperature alloys.

Table II—Some Common High Temperature Alloys

Iron Base Alloys		Nickel Base Alloys continued	
Alloy	Characteristics		
Stainless Steel SAE 3021, 3047	These materials are stabilized 18% chromium, 8% nickel basic non-hardenable stainless steel. They have excellent fabrication characteristics, are weldable and fully corrosion resistant. They are commonly used in elevated temperature applications to 1500 F where medium strength and corrosion resistance is required.	Incoloy	A critical-alloy-reduced version of Inconel X with somewhat lower properties.
		Nimonic 75, 80, 90	A series of British developed alloys similar to Inconel X in composition and function.
		Hastelloy B	A Haynes Stellite development that contains molybdenum as the major alloying element and no chromium. The absence of chromium and high percentage of molybdenum lowers its scaling temperature. It has excellent strength to 1600 F and higher.
Stainless Steel SAE 30310	A standard SAE steel which contains 25% chromium and 20% nickel. This material has excellent scaling resistance up to 2000 F and over. It is used where high strength is not needed at temperatures to 2200 F.	Hastelloy C	Another Haynes Stellite product that contains chromium for increased scaling resistance and has been used for high strength applications to 1800 F and above. However, its high critical alloy content and fabrication characteristics limits its use.
19-9DL, 19-9 DX	A low alloyed (with molybdenum and tungsten) modified stainless steel. It retains strength comparative to most of the high temperature alloys up to 1400-1500 F. An excellent low-critical-alloy-index material for general structural use up to 1500 F.	Hastelloy X	A critical-alloy-reduced version of other Hastelloys that combines excellent scaling resistance with good strength. It is being used more and more in combustion chamber and component applications of all powerplants.
16-25-6	A chromium, nickel, molybdenum alloy available in bars and forgings. This alloy has been a commonly used turbine wheel material for service up to about 1500 F.		
A-286	An age hardenable stainless steel material that can be used up to the low end of the temperature range, around 1200 F.		
17-4 PH, 17-7 PH	Age hardenable stainless steel materials that have high strength-weight ratios at lower temperatures, but that find some application in the temperature range around 1000 F.		
Discalloy 24	An age hardenable stainless steel primarily used as a forged wheel alloy up to 1300 F.		
Nickel-Base Alloys		Cobalt- and Mixed-Base Alloys	
	Characteristics		
Inconel	An 80%-nickel, chromium, iron alloy that has seen much use as a low strength, high corrosion resistant material at elevated temperatures. It is hot short (low ductility) at 1200 F and is not commonly used in powerplant structures today.	N-155 (Multimet)	A chromium, nickel, cobalt, iron mixed base alloy that has become somewhat of a work horse in the temperature range from 1200 F on up. It is considered a scrap base alloy. It has good high temperature properties to 2000 F compared to all other alloys, can be readily fabricated, requires no heat-treatments.
		S-816	A mixed-base alloy with 3% or higher of columbium, tungsten, and molybdenum. It is high on the critical alloy list, has excellent strength at the higher temperatures. It has been used extensively for forged turbine blades.
		Refractalloy 70	A mixed-base alloy with high molybdenum that has good elevated temperature properties. It is not widely used.
		L-605 (H.S. 25)	A cobalt-base material that is the strongest of all high temperature alloys above about 1600 F. It is only used where high stresses exist at the upper end of the temperature range (1700-2200 F). It has high critical alloy content.
Inconel X	An age-hardenable offspring of Inconel containing titanium and aluminum for age-hardening that tops in strength up to 1600 F all high temperature alloys. It is difficult to fabricate, must be heat-treated after forming. It has found widespread use as a combustion chamber material for afterburners as well as many other applications.	H.S. 21, 23, 30, 31	A series of cobalt-base casting alloys. They are commonly used for cast turbine blades and other high temperature applications requiring high strength.

conductivity, differential heating and hot spots can easily lead to severe distortion and actual burning through the metal. Thermal stresses causing failure are often the result of inability to distribute heat evenly throughout a part.

A property only recently seriously considered by the powerplant designer is emissivity. This property is a measure of the amount of incident radiant heat that can be absorbed into or leave a given surface. Properly speaking, emissivity is the ratio of heat radiated by a body to that radiated by a black body at the same temperature. Absorptivity is heat absorbed relative to that of a black body at the same temperature. For common combustion chamber materials, emissivity is numerically equal to absorptivity. An emissivity factor of 1 is that of a black body which will absorb the maximum amount of heat and also dissipate the maximum amount. It is important in combustion chambers to have an inside surface with as low an emissivity factor as possible, to reflect a maximum amount of radiated heat from the combustion gases. On the other hand, a ramjet engine combustion chamber outer surface is open to the sky and should have as high an emissivity factor as possible to radiate more heat from the wall to the sky. The factor of emissivity can mean hundreds of degrees in operating wall temperature.

Fabrication Characteristics

In general, high temperature alloys present greater difficulties to the fabricator than either alloy steels or stainless steels. Since the fabrication characteristics of 18-8 type stainless steels have been fairly well determined, it is a common practice to compare the high temperature alloys to stainless steels when considering the various fabrication methods.

Welding—All of the high temperature alloys can be fusion welded satisfactorily. Hellarc welding is best for most of the alloys because this process offers the least chance of contamination by carbon and oxides. The use of flux coated rods or liquid or paste fluxes introduces the problem of complete flux removal prior to elevated temperature service. The finish configuration of welds, especially in sheet material, has a great effect on the performance at elevated temperatures. For this reason, the optimum welded joint is a tight butt weld made automatically by the hellarc method adding no filler metal and roll leveling the resultant bead. Roll leveling mechanically forces the weld metal into the plane of the base metal producing a flush, stress-relieved, cold-worked joint.

Resistance-welded joints are readily made using somewhat greater pressures than are necessary for stainless steel.

Forming—High-temperature alloys can be formed by all of the commonly used forming techniques. They tend to work harden rapidly and require roughly twice the number of intermediate anneals as stainless steels. Minimum bend radii are somewhat larger than those for stainless steels, and provisions must be made for greater springback. Annealing procedures are performed at temperatures generally above 2000 F, requiring high-temperature furnace equipment and special equipment for removing scale.

Machining—The high temperature alloys are all hard to machine. In general, the mixed and cobalt-

base materials are most difficult, the nickel-base alloys next, and the iron-base alloys the easiest to machine. A good value for estimating the speed of machining high temperature alloys is one third to one half the speed of stainless steels for all normal cutting operations, such as milling, drilling, and shaping.

Forging—Forging is possible on practically all the high temperature alloys. However, forging pressures must be higher and temperatures hotter than for stainless steels. Tolerances in the as-forged condition may not quite compare with those of stainless steel or alloy steel parts because of the more difficult working conditions.

Casting—Many of the high temperature alloys are cast by several of the casting methods. When complicated parts are desired from hard-to-machine alloys like Haynes Stellite 21, 23, or 31, the parts are investment cast to finish shape. Turbine blades and afterburner nozzle segments are typical of parts that are cast to finish shape. Many of the cobalt-base alloys are fabricated only by casting.

Scaling and Corrosion Resistance

As the service temperature of a part climbs to temperatures above 1500 F, scaling becomes an important factor in determining the choice of materials. In addition, the corrosion effects of hot combustion gases on burner components must be considered. The chromium content of a high temperature alloy is the best, but not the only, indication of scaling resistance. Chromium contents of 15-20% in high temperature alloys will result in scaling resistance up to 1900 F. As the chromium content is increased to the 25% of SAE 30310 stainless steel the free scaling temperature increases to 2200 F. At and above this temperature, all alloys have a decided scaling rate. However, since scaling is determined by temperature, atmosphere, and time, the short service lives of guided missile powerplants enable parts to function at temperatures of 2000 F and higher. The service life expected of afterburners limits their top metal temperatures to about 1900 F. The much shorter service life of ramjet engines extends their top operating temperatures to 2000-2200 F. Probably the two most scaling-resistant materials available today are SAE 30310 stainless steel and Hastelloy X, primarily due to their high chromium content.

Limitations of High Temperature Metals

Strength—Usable strength levels for high temperature alloys vary with the application. For short time applications under low loads and a simple stress pattern, service temperatures as high as 2200 F have been considered for structural components of ramjet engines. In other applications, such as high speed, long service life, turbine blades, 1600 F is considered top today. Each application must be rated with respect to load, service time and other factors to determine a ceiling temperature of operation. Many times an alloy can be used for intermittent, short time service at temperatures considerably above the normal operating temperature.

Melting Point—Combustion temperatures using fuels known today are already higher than the high-

est melting point metals. Most of the refractory metals with melting temperatures over 3000 F are brittle and susceptible to rapid oxidation. The melting point of the basic structural metal element, iron, is 2800 F. As alloying elements are added, this temperature becomes lower. Cobalt and nickel melt below 2800 F, their alloys melt down in the range 2400-2600 F. In general it can be stated that all of the present structural materials capable of unprotected operation at temperatures above 1500 F melt below 2700 F. To the combustion engineer, 2700 F is a low gas temperature.

The present research efforts to produce ductile alloys of molybdenum, chromium, titanium, and zirconium for service at temperatures in excess of 2000 F are progressing slowly. The high melting points of these elements, all above 3000 F, are offset by lack of oxidation resistance, lack of strength, brittleness, production difficulties or fabrication difficulties. Molybdenum (melting point=4750 F) catastrophically oxidizes at about 1800 F, tends to produce brittle alloys, and is very difficult to fabricate, especially weld. Titanium alloys (melting point about 3100 F) presently produced drop off markedly in strength above about 1000 F and embrittle when exposed in air to temperatures above about 1400 F. Chromium and its alloys (melting point about 3400 F) investigated to date are too brittle for structural applications.

Most of the other high temperature melting point metals are so brittle or susceptible to scaling that little development work on structural alloys of tungsten, rhenium, tantalum, and other high melting point elements for high temperature service is being done. So, we are nearing the ultimate in high temperature structural metals at service temperatures considerably below the combustion gas temperatures known today. Cermets and refractory hard metals (silicides, borides, carbides, nitrides) seem to be the principal hope of the future.

Ceramic and metal coatings

One way to make more effective use of metals at high temperatures is to stabilize their surfaces by protective coatings. Vapor-deposited metals or ceramics, solution ceramics, and other proprietary coatings are being used, but not as much as fired-on ceramic coatings and diffused aluminum metal coatings. Combinations of ceramics and metals (cermet) coatings have unique properties and probably will be the next step in the field.

Until now, more research and development has been done on ceramic coatings than any other. Exhaust nozzles of liquid fuel rockets have been successfully coated and liquid cooled nozzles protected effectively. Ceramic coatings are not effective on uncooled rocket nozzles.

Ceramic coatings are widely used on turbojet compressor blades, combustion chambers, transition liners, tailcones, afterburner flame holders, afterburner inner liners, and adjustable exhaust nozzles.

High alloy ramjets, coated on the inside, are performing satisfactorily. The ceramic coating prevents carbon pickup, intergranular corrosion, and stress corrosion cracking. In a reciprocating engine a ceramic-coated SAE 30321 exhaust manifold completed 5100 hr of operation without deterioration—almost three overhaul periods.

Ceramic coatings are made by mixing minerals,

ALLOYING ELEMENTS

Element	Function
Iron	A foundation element for structural metals
Nickel	Austenitizer; improves oxidation resistance in stainless steels; adds high temperature strength; improves corrosion resistance
Cobalt	Base metal for highest-strength high-temperature materials; improves high temperature strength in mixed alloy materials (N-155)
Chromium	Primary source of oxidation resistance
Molybdenum	Improves high temperature strength; adds corrosion resistance; has precipitation hardening potential in some alloys
Tungsten	Improves high temperature strength
Columbium	Stabilizing element in austenitic stainless steels; adds high temperature strength
Titanium	Same as cobalt, but has precipitation hardening value in some alloys
Aluminum	Primarily added as precipitation hardening agent (17-7 PH, Inconel X)
Vanadium	Thought to improve creep resistance
Silicon	Added up to about 2% to improve oxidation resistance in some stainless steels

smelting them, and fritting the smelt. Fritting is the process in which molten liquid mixture is dumped into water so that it can be readily broken up during subsequent milling. The frit is milled with water to make what is known as a ceramic slip. Mill additions are sometimes made by adding refractory oxides or other materials to develop desired properties.

After milling the slip is adjusted so that it can be applied to clean metal by spraying, dipping, or slushing. The ceramic coating is the final result obtained by furnace firing the coated metal, thereby combining two materials with completely different atomic makeups to provide outstanding high temperature surface protection.

Ceramic coatings have several limitations, however. Since the coating is primarily glass, it is brittle and has low thermal and mechanical shock resistance. Bonding to the metal is difficult. It also has a wide softening temperature range so that at high temperatures it may not be able to resist impingement erosion.

Cermet Coating—Some of these limitations may be overcome by coatings which are combinations of ceramics and metals—called cermets. The ceramic

A seminar on "High Temperature Materials for High Speed Aircraft" was presented by the SAE Southern California Section in cooperation with the University of California at Los Angeles on Dec. 6-8, 1954, in Los Angeles. This article is based on the following papers presented at the seminar:

M. R. Kinsler, North American Aviation, Inc.

"The Aerodynamic and Power Plant Heating Problem in High Speed Aircraft"

C. S. Davis, Northrop Aircraft, Inc.

"Thermal Limitation of Common Aircraft Materials"

C. W. Alesch,

Convair Division, General Dynamics Corp.

"Some Trends in Elevated Temperature Resistant Aircraft Materials"

S. G. Demirjian, General Electric Co.

"Technological Advancements in Jet Engine Materials"

T. L. Burton, Douglas Aircraft Co.

"Hot Sandwiches-Honeycomb and Sandwich Structure"

B. L. Manire, Northrop Aircraft, Inc.

"Transparent Enclosure Materials"

F. E. Clark, North American Aviation, Inc.

"High Temperature Problems Associated With The Use of Rubber Parts in Aircraft"

L. O. Curtis, Douglas Aircraft Co.

"Open Flame Testing of Various Fiberglass Laminated Air Ducts at 2000 F"

M. Tiktinsky, Lockheed Aircraft Corp.

"The Selection of Metals for Airframe Components as Affected by Operating at Elevated Temperatures Up to 600 F"

J. W. Huffman, North American Aviation, Inc.

"Application of Metallic Materials for Aircraft Structures in the Temperature Range 600-1100 F"

A. V. Levy, Marquardt Aircraft Co.

"Application of Metals for Power Plants in the Temperature Range 1100-2400 F"

J. V. Long, Solar Aircraft Co.

"Ceramic and Metal Protective Coatings for High Temperature Materials"

A Special Publication, SP-128, compiled of the above 12 papers, is available from the SAE Special Publications Department, 29 West 39th Street, New York 18, N. Y. Price: \$3.50 to members; \$7.00 to non-members.

provides the high temperature resistance; the metals provide ductility and resist impingement erosion.

Some cermet coatings are better than ceramic coatings for protecting low alloy metals. Several proprietary cermets look promising. The most widely publicized is the nickel-magnesia coating developed at Ohio State University.

Cermet coatings can be made by using a good high-temperature ceramic coating and adding powdered metals to it. The National Bureau of Standards reports Microbraz, which is a high temperature nickel-based brazing powder, may be added to the Bureau of Standard's frit and fired on SAE 30321. Approximately four times as much metal as ceramic is used in the combination. This coating has very effective erosion resistance, but because of the high nickel content does not have good resistance to sulfur and lead combustion products.

Metal Coating—Diffused aluminum coatings seem

to be the most effective metal coat. Chromizing has been used for protecting low alloy engine parts in a number of instances with effective results. Metals may be coated with aluminum by calorizing, plating from a vapor phase of aluminum chloride, metal spraying, electroplating, cladding, and casting. All aluminum coatings, no matter what process, markedly decrease the oxidation of metals at high temperatures.

For aircraft engines the aluminum coating is usually followed by diffusion at a high temperature to develop an intermetallic compound. Iron-aluminum, nickel-aluminum, or cobalt-aluminum compounds are formed either singly or in combination depending upon the composition of the basic metal. The compound layer normally consists of several intermediate phases where aluminum has been diffused into a nickel-base alloy.

Stress rupture tests show that aluminized nickel-base alloy gives a ten-fold increase in the stress

rupture life of a coated part, permitting the design engineer to use the metal to its maximum indicated strength.

One limitation of the aluminizing process is that it is difficult to coat parts of complex shape where blind holes, grooves, and sharp edges are encountered. A new process—in which the part is dipped, dried and then fired similar to enameling processes—seems to overcome this drawback.

Aluminum coatings will protect SAE 30321 from oxidation at temperatures up to 2300 F for short periods. Aluminized SAE 1010 has been tested over 7000 hr at 1500 F without loss of weight. Compared to ceramic coatings, which find it difficult to last 400 hr at 1500 F, this is amazing.

The future of high speed, high temperature flight looks to the laboratory for new methods of protecting metals.

Lube Oil Additives . . .

. . . proliferate and undergo steady refinement to keep pace with engine development and changes in driving habits.

Based on paper by **P. E. Pfeifer** and **F. T. Finnigan**, Pure Oil Co.

REFINING processes which enhance certain properties of an oil may leave deficiencies in others. Also, the uses to which an oil is put may require properties not to be had by crude oil selection or refining techniques. This is where additives come into the picture. They fill in the gaps, thus allowing the refiner to take full advantage of the best properties of the crude oil stocks and refining methods at his disposal.

The pour depressant, one of the first additives to be used commercially, enhances the low temperature fluidity of oil, or pour point, by preventing wax crystals from adhering. It cannot prevent the formation of crystals. That is basically a job of selecting the raw materials and refinery dewaxing techniques.

Inhibitors came into use in the 1930's to handle the problem of oil oxidation. Oxidation products are harmful and they act as a binder for external contaminants entering the crankcase. Inhibitors are employed to interrupt the chain reaction before the harmful products are formed. And certain corrosion inhibitors are used which react with bearing surfaces to form protective coatings.

Detergents act as dispersants rather than as cleansing agents. Their job is to keep particles of soot, dirt, fuel residues, and oil oxidation products dispersed in the oil, to be carried out of the engine when the oil is changed. Crankcase oils are designed with detergent capacity great enough to carry through a normal drain period with a factor of safety.

The churning of oil in the crankcase entrains oil and causes foaming. If allowed to persist, slugs of air could enter oil lines, interrupt the flow of oil, and endanger bearings. There might even be leakage through the dipstick hole or crankcase ventilator tube. Antifoam agents discourage foaming by reducing surface tension which allows air bubbles to pass more readily out of the oil.

The newer additives have come into being to meet the demands of modern engines and change in driving habits. The modern engine is a high output, high efficiency, compact machine. It has higher localized temperatures, more heavily loaded parts, and closer fitting components with less tolerance for wear and deposition. It powers cars used for short trips and sustained high speed driving. Both

engine design and use, therefore, make lube oil performance more critical.

Low temperature operation calls for a clean engine so that hydraulic valve lifters won't stick, so we have proper matching of detergent-inhibitor combinations and the base oil to minimize the deleterious effects of contamination.

Then there are special wear problems centering around the valve train, including scuffing, spalling, and wear of lifters and camshafts. Unfortunately, certain oil-additive blends will give excellent service in one engine and result in serious distress of cam or lifter faces in others. The trouble usually occurs on only about half of the lifters or lobes, indicating that at least a few of the cams were lubricated satisfactorily by the same oil. Certain materials added to the oil have been found to prevent occurrence in a particular engine. But this does not end the problem because the same material may cause worse trouble in another.

Viscosity index improvers have contributed greatly by reducing the tendency of an oil to thin out as temperature increases. They are quite stable, do not affect oxidation or cause serious deposition.

And now come multigraded oils with viscosity-temperature characteristics such that the oil remains fluid at low temperature to insure cold starting and good oil circulation during warm-up, and has enough body at high temperature to give protection at high speed operation.

When using a viscosity index improver it is possible, though not necessary, to omit the bright stock from the oil. And that is another advantage of multigraded oils using viscosity index improvers. Bright stock is a refined mineral oil taken from the bottom of the still which contains heavy, high boiling materials. Most conventional oils are made up of blends of bright stock and lighter lubricating oil stocks in proportion necessary to achieve desired viscosity. With bright stock omitted the character of engine deposits are such as to show a marked reduction in octane requirement increase and surface ignition tendencies. (Paper "Lubricating Oil Additives and the Modern Engine" was presented at SAE Milwaukee Section, Dec. 3, 1954. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to non-members.)

GM Research Labs

Develop New

IN developing a new turbine bucket alloy, Research Laboratories Division of General Motors Corp. has gone a step further than alloy formulators associated with steel producers usually go. They have not only worked out a composition that combines high strength and low strategic alloy content. Be-

ing steel users, they have also worked out foundry procedures in detail for the alloy.

The result is GMR-235, a nickel-base casting alloy balanced to give top performance plus reasonable ease of manufacture.

Table 1 gives composition limits of GMR-235. The Labs tried many variations on this recipe, but these proportions gave the best overall results. The aluminum and titanium give room-temperature strength and ductility. The boron contributes to high-temperature strength and ductility. The three elements in the proportions listed insure a desirable combination of properties throughout the temperature range, even with as much as 12% iron.

Fig. 1 shows strength and ductility from room temperature to 1700 F. Fig. 2 shows stress-rupture data. (The range results from variations in chemical composition, test conditions, casting soundness, and crystal orientation.) Other data not shown indicate that GMR-235 creeps much less than certain other turbine bucket alloys—and GMR-235 gives more consistent results.

Aging GMR-235 at 1800 F for 5 hr increases its damping capacity and its stress-rupture life, supplementary physical testing showed. Thermal shock tests indicated that GMR-235 will corrugate or warp rather than crack in brittle failure after alternate heating and quenching.

Foundry Procedures

GMR-235 was developed initially as an investment casting alloy. As such it had to be furnished as qualified stock in a form suitable for remelting. Both the high-frequency induction furnace and the direct arc furnace have proved suitable for master heats. The induction furnace is being used for heats up to 1000 lb, while 6000-lb heats are regularly produced in direct arc furnaces.

The latter offers the advantage of employing refining techniques. However, up to 90% scrap in the form of gates and risers has been recharged in the induction furnace without detrimental effect on metal quality. No accumulative effect from recharging gates and risers into the induction furnace has been detected in over two years of production without refining. However, low-grade scrap such as

Table 1—Chemical Composition Limits of GMR-235 Alloy

Element	%
Carbon	0.10 - 0.20
Manganese	0.25 max
Silicon	0.60 max
Chromium	14.00 -17.00
Iron	8.00 -12.00
Molybdenum	4.50 - 6.00
Aluminum	2.50 - 3.50
Titanium	1.50 - 2.50
Boron	0.025- 0.100
Nickel	Balance

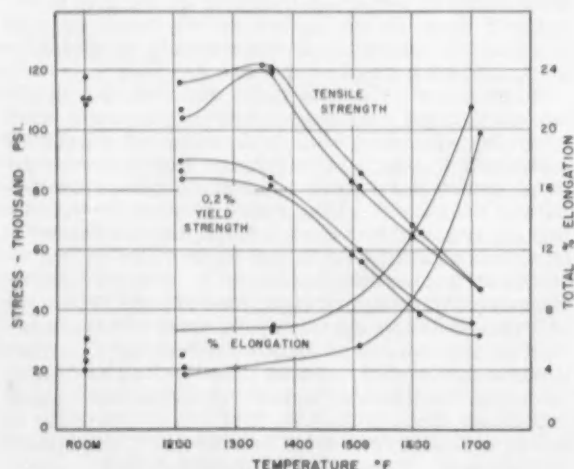


Fig. 1—Tensile properties of GMR-235 at high temperatures.

D. K. Hanink, F. J. Webbere, A. L. Boegehold

Research Laboratories Division, GMC

Based on paper "Development of a New Gas Turbine Super Alloy GMR-235" presented at the SAE Golden Anniversary Annual Meeting, Detroit, Jan. 14, 1955. This paper will be published in full in 1955 SAE Transactions.

Turbine Bucket Alloy

ladle skulls and furnace drippings containing a high percentage of nonmetallics must be refined in the arc furnace capable of handling a basic slag. The segregation tendency associated with the low density of the aluminum and titanium additions can be controlled within useful limits by careful melting practice.

The master heat alloy is produced in shot form for convenience in remelting. Suitable melting stock may also be produced as bar or piglet, but the cost is greater and blending of several heats is ruled out. This is an important consideration since the consolidation of several heats into one allows significant saving in stress-rupture qualification test time.

Although both aluminum and titanium form refractory oxides which may result in surface folds in the casting, this type of defect has been brought under control in the remelting and casting operation. Use of a small furnace for remelting an individual charge just sufficient to fill a single mold allows the inverted mold to be clamped directly to the top of the furnace. This arrangement, which is common in the investment casting industry, provides for purging of the furnace and mold atmosphere and close control of the pouring operation.

Economical remelting requires the use of the induction furnace. Low thermal conductivity through the shot during initial stages of melting results in unduly long melting time in the indirect arc furnace which has been widely used to produce investment castings. Use of barstock in place of shot and oscillation of the furnace during melt-down allow use of the indirect arc furnace, but the uncertainty of carbon pickup from the electrode and the vigorous stirring achieved in the induction furnace have resulted in exclusive choice of induction melting for the recasting operation. There is a battery of such furnaces at Fabricast Division of General Motors Corp.

It is essential to avoid entrainment of dross as the metal flows into the mold cavity and to melt clean to assure accurate optical temperature measurements. This is accomplished by melting under a protective blanket of argon, allowing as little back diffusion of air as possible when removing the fur-

nace cover and placing the mold in position on the casting furnace.

After the inverted mold is clamped firmly to the top of the furnace, the assembly is rolled over as a unit to transfer the metal from the melting crucible to the mold without exposing the molten metal to air. The speed at which this roll-over occurs is important and should be just fast enough to avoid misruns at the desired casting temperature.

GMR-235 containing both aluminum and titanium has proved to be compatible with silica investment molds when the casting conditions are properly controlled. Excessive metal or mold temperature will promote a reaction between the molten alloy and the silica investment material. Purging of the mold cavity, section size, rate at which the mold is filled, and alloy composition must also be considered. Greater difficulty is experienced with metal-mold reactions when the aluminum content is low (less than 2.5% aluminum).

When the design of the casting requires conditions which may be conducive to metal-mold reac-

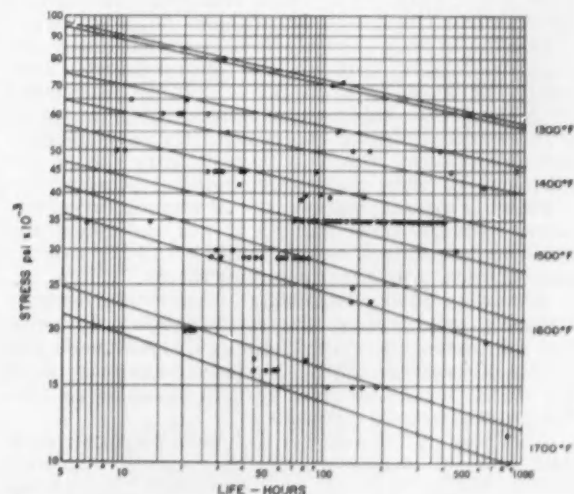


Fig. 2—Stress-rupture properties of as-cast GMR-235 at high temperatures.

tion, alumina precoats may be used. Although there is no reaction tendency with alumina, silica precoats are normally preferred because of decreased cost and improved surface smoothness.

Inasmuch as GMR-235 is subject to formation of oxide films which show up as surface folds when trapped in the casting, special consideration must be given to gating methods which will eliminate turbulence of the molten metal and entrapment of air. The importance of gating practice was emphasized when redesign of the gating for stress-rupture test bars resulted in an increase in the high-temperature properties comparable to specimens removed from bucket castings.

To arrive at the improved gating system, fluid flow studies of various gating systems were conducted, using water in transparent lucite molds. Application of improved gating techniques to turbine bucket castings has resulted in improved casting recovery. The improved foundry recovery rep-

resenting adequate inspection controls has resulted in production of turbine bucket castings conforming to aircraft standards.

The value of all this development work is reflected in actual field service reports covering engines equipped with GMR-235 alloy. In two years of volume production over 500 tons of this alloy have been melted and cast into various shapes for gas turbine service. In flight tests, a control group of 114 engines representing a larger number of production engines equipped with GMR-235 buckets has accumulated an average of 183 hr of service time, 56 of which engines exceed 200 hr of engine service. Twelve sets of buckets have been run more than 500 hr, with maximum time exceeding 800 hr.

This successful field experience without a single bucket failure has resulted in unlimited installation on the engine model covering the service tests and lends credence to the engineering data constituting the laboratory development work.

Airborne Weather Radar . . .

. . . helps passage through thunderstorm area. Airlines debate merits of 3.2- and 5.6-cm wavelength since neither is superior on all counts.

Based on paper by **Richard N. White**, Trans World Airlines, Inc.

AT Trans World Airlines we believe each airline must answer the wavelength question for itself by weighing the capabilities and deficiencies of the 3.2- and 5.6-cm wavelength against its own operational requirements. That's what we did and we reached several conclusions.

Radar information permitting the pilot to avoid storm areas entirely is not enough, particularly because aircraft are often confined to closely-shaped airways which allow very little lateral deviation. Twenty-odd years of operation tell us that two airplanes can be quite close together in a thunderstorm area, yet one may fly through with very little turbulence while the other experiences considerable.

One major requirement, then, is to determine the smoothest path through the thunderstorm area while the airplane is in heavy rainfall associated with the area. This need dictates maximum penetration and minimum target distortion due to rainfall attenuation, which in turn dictates the longer wavelengths with their lower rainfall attenuation.

Existing ground beacons are of secondary importance because their setting is not optimized for TWA routes. Other carriers might find the usefulness of these beacons a deciding factor.

According to available data, 3.2-cm radar terrain mapping might show the most detail. However, the difference is not great enough to influence our choice of wavelength since we have no primary need for using fine detail from terrain mapping as primary navigational information.

The nose of TWA Super Constellations can contain a 34-in. diameter antenna. Many airplanes cannot use an antenna with diameters larger than 18 or 20 in. The larger antenna enables us to regain all the definition lost by using the 5.6-cm wave-

length. (A 34-in. dish at 5.6 cm gives approximately the same half-power beam width as an 18-in. dish at 3.2 cm.)

The 5.6-cm flight tests conducted by United Air Lines in the summer of 1953 seemed to confirm a conclusion reached at McGill University that 5.6-cm radar was superior for rainfall penetration. These tests also indicated some very high rainfall densities in thunderstorm areas.

TWA favors the 5.6-cm wavelength for these many reasons even though the wavelength controversy still continues to some extent among highly qualified radar specialists. (Paper "Weather Radar Installations in TWA Constellations" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 18, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Based on discussion . . .

Scott Flower, Pan American World Airways, Inc.

Pan American has accumulated approximately 1300 radar operating hours on flights throughout the world, using a 3.2-cm wavelength. The radar has proved very effective in the avoidance of turbulence due to hail, cloud build-up, or other forms of precipitation, especially since this airplane on occasion has flown side-by-side with other PAA flights through the same weather, and significantly smoother flights were experienced. The beam width of the antenna radiated pattern is very narrow (3.8 deg); hence the set is not effective in the detection of other aircraft in the same area.

The designer can tame residual stresses to work for him instead of against him, if he exercises . . .

4 controls on residual stress

George Sachs,

Syracuse University

Based on paper "Control of Residual Stresses in Practice" presented at SAE Golden Anniversary Annual Meeting, Detroit, Jan. 14, 1955. This paper will be published in full in 1955 SAE Transactions.

RESIDUAL stresses which counteract load stresses lessen the effective load. Since applied loads are generally tensile, residual compressive stresses are generally beneficial—and residual tensile stresses are generally damaging.

Effects of residual stresses depend primarily on stress magnitude at exposed surfaces. Therefore, compressive surface stresses are usually the designer's goal. Here's a review of ways he can achieve them:

1. Choose materials, processes, and heat-treatments that result in a favorable residual stress condition. For example, case-hardened steels have high compressive stresses in the case. So do flame-hardened and induction-hardened steel parts. However, certain plating operations which develop hydrogen in the metal's outer layers set up compressive residual stresses.

2. Be sure that finishing operations such as grinding and straightening do not introduce unfavorable residual stresses. Careless grinding may heat the surface to the extent that severe tensile stresses develop as the surface cools. Stretching bars to straighten them may also deform them plastically, thereby introducing microstresses which affect dimensional stability, elastic properties, and electrical resistance.

3. Anneal to relieve residual stresses. A stress-relief anneal is the most effective control measure for annealed, normalized, and cold-worked metals. However it usually cannot fully relieve stresses in heat-treated alloys without changing their strength characteristics.

4. Apply a final mechanical treatment like shot-peening, which favorably affects the residual-stress pattern. Such surface treatments have been in use for decades, having been introduced long before the role of residual stresses was recognized. An early example is the surface rolling of railway axles to "burnish" them. The rolling of threads and of bolt shoulders are other applications of surface treatments to produce a favorable, compressive residual stress.

THE paper from which the accompanying article is abridged includes an extensive bibliography. The complete paper, including the bibliography, is available in multi-lith form from SAE Special Publications Department at 35¢ to members, 60¢ to nonmembers.

An even more extensive bibliography having 1545 entries is available as SP-125, "Bibliography on Residual Stress" at \$5.00 to members and \$10.00 to nonmembers.

Historic Personalities . . .

. . . move through this running story of Willard F. Rockwell's about people and events which have made the automobile industry what it is today. Here are a few of those you will find mentioned:

Durant	Ford
Couzens	Alden
Rackham	Wilson
Chevrolet	Liebold
Buick	Wills
Raskob	Mayo
Knudsen	Hawkins
Dodge	Woodall
Mott	
Sloan	
Sorenson	
Klingensmith	

THE relatively young automotive industry's half-century record furnishes some vivid examples of how quickly the poor got rich, and, on the other hand, how rapidly even the very rich could lose their fortunes—and occasionally regain them—or finally pass away in poverty and obscurity.

GM started Companies—and People

General Motors originated from the pioneer engineering work of a great inventive genius, **David Buick**, and a great salesman and bold promoter, **W. C. Durant**. Both of them died in poverty, after attaining great wealth. Buick completed and sold the first Buick in July, 1904. It was bought by a doctor, who took Mr. and Mrs. Durant for a ride in the new car. As a result of that thrilling demonstration, Durant purchased control of Buick's company, which had been organized with a cash capital of \$35,000. The company built a plant in Flint, Michigan. In 1910, **Charles Nash**, who started as a dollar-a-day shop worker, became its general manager. **Walter Chrysler** succeeded Nash, who became President of the Jeffery Co.—now part of American Motors. In later years, **Harlow Curtice** became president of Buick in his rise to president of General Motors.

General Motors not only merged many companies into one, but started many men into independent motorcar manufacturing, and eventually into other mergers.

Durant—Ups and Downs

Durant organized General Motors Corp. in 1908, and was first to conceive a plan for producing a complete line of motorcars to cover the entire sales field—from the low-priced car to the most luxurious high-priced car. In that year he took over the Elmore and the Cartecar, explaining to his stockholders: "The motorcar industry is in such a state

MEN Who Made

of flux or unpredictable trends, that it is wise to collect a variety of designs to avoid missing the eventual winning type."

In July, 1909, Durant took control of Cadillac, which was first started in 1899 as the Detroit Automobile Co. (It is most interesting to note that **Henry Ford** was one of the original stockholders in 1899, and that the Detroit Automobile Co. was organized to produce a car developed from the design of young Ford's home-built car.)

Ten thousand dollars was paid into this company, which, according to its records, expected to finance production of 10 cars. But, after \$86,000 had been spent without producing a car, Ford resigned and was paid \$1800 for a patent he had obtained on a carburetor. Shortly after General Motors took over the Cadillac company in 1909, Durant's ambitious operations ran so far in excess of his financial resources that he was forced to relinquish control of General Motors to the bankers.

Durant had started his career in Flint, where his family was well known and his grandfather had been a governor of the State of Michigan. Nevertheless, he started without any financial backing, and became rich through his purchase for \$50 of an invention which enabled him to build up one of the largest carriage plants in the country.

Outside of organizing companies, merging companies, and building up sales forces for both his shares and his products, Durant's greatest contribution to the automotive industry was derived from his carriage manufacturing experience. There, if he was not the first, he was the best-known exponent of the assembly-line methods. He had built up his carriage production by farming out the parts to other manufacturers, who, in becoming mass producers of certain parts, built them better and cheaper than any of their sprouting young assembly-line customers.

Durant, who always placed his emphasis on the financing phase of business, realized that he could produce more carriages or more cars with less capital if someone else furnished him with parts. If business declined, the manufacturers of parts had the financial burden of carrying their own plants and liquidating their own inventories. Despite his apparent recognition of this theory, on both occasions when he lost control of General Motors his

the Automotive Industry

finances ran out because his large inventories could not be liquidated in time to satisfy the bankers.

After losing control of General Motors Co. in 1910, Durant was considered broke financially, but he was never "broke" in spirit up to the day he died. When he learned that **Louis Chevrolet**, the famous French race driver, was having a special racing car built by **William H. Little**, who owned a small shop, Durant bought the shop and the right to use the name "Chevrolet." Then he gained control of the Republic Motor Car Co. at Tarrytown, N. Y., and started to produce Chevrolet cars.

du Ponts Come into GM

About this time he became associated with **John J. Raskob** and, through him, secured his first financial support from the du Pont family. The du Ponts aided him in buying General Motors' stock, and, by 1915, Durant was able to reorganize his operations under the name of the Chevrolet Motor Car Co. of Delaware, with a capital of \$20,000,000. With the help of the du Ponts, he bought control of General Motors. Then, by an exchange of stock between General Motors and Chevrolet, Durant and his associates had complete control of General Motors in the spring of 1917.

While Durant was out of General Motors, he had acquired, by purchase or merger, various accessory plants. The most important of these was the Dayton Engineering Laboratories, with its trade name, "Delco." In that deal, he acquired the services of **Charles F. Kettering**, who is still considered the top engineering genius in the General Motors organization. He also purchased the Hyatt Roller Bearing Co., of which **Alfred P. Sloan, Jr.** was the chief executive; also the Weston-Mott Axle Co., which later made **Charles S. Mott** the largest individual owner of General Motors' stock.

General Motors operated successfully through World War I, but Durant had recognized the great opportunities for motorizing agricultural machinery and implements. So, he poured millions into the organization of a Farm Tractor Division.

After World War I, a period of inflation resulted in a market crash. Durant was just one individual among the millions of victims.

In August, 1920, Durant resigned as president of Chevrolet. At the same time, **William S. Knudsen** became manager of manufacturing in the Chevrolet division, having left Ford after several years' association.

Because of the great reputation he had made with General Motors, Durant was able to form a new corporation—Durant Motors, Inc. There, he started with every intention of building another line of cars to challenge General Motors, which he had originally organized.

In the crash of 1929, Durant went down for at least the third time, and was never able to recuperate his fortune thereafter. David Buick had retired as a wealthy man, but lost his fortune in later years.

Chrysler Takes Charge

Walter Chrysler was president of Buick and vice-president of General Motors when as a manufacturer, he clashed so frequently with President Durant, the promoter, that they agreed to part company. Chrysler spent several years reorganizing the Willys-Overland Co., and then saw his opportunity in the Maxwell Motor Car Co. The pioneer Maxwell

A Fascinating 50 Years

Here is a fascinating account of men whose names and deeds comprise the first 50 years of U. S. motor vehicle progress. It is told by a man who himself has played a major part in that progress.

Over 40 years in the automotive industry, Willard F. Rockwell has known personally almost every one of the pioneers. The companies of which he is currently chairman of the board have furnished parts to major motor vehicle companies since the first days of mass production.

In this article, he speaks of a stirring 50 years in which he and his friends and associates have participated abundantly.

Co. went into federal receivership in 1913, but, in 1917, the Maxwell Co. took over the Chalmers plant in Detroit. Then, in May, 1921, Walter Chrysler was placed in charge of the operations of Maxwell and Chalmers, which eventually became the Chrysler Motor Car Co.

One of the big arguments between Chrysler and Durant had occurred after Chrysler, as president of GM's Buick Division, announced he had made a contract with the A. O. Smith Co. for the purchase of car frames produced under a new mass-production method. Chrysler claimed this process would save Buick \$1,500,000 a year. When Durant immediately announced that he would build a General Motors frame plant in Flint, Chrysler felt that Durant was on the wrong track and would certainly plunge himself and General Motors into new financial difficulties.

Chrysler Was Right

Two things proved Chrysler was right: first, Durant's loss of General Motors' control in 1920; second, Chrysler's phenomenal success. This success was based upon Chrysler's idea of designing a good line of cars and inducing the best parts manufacturers to produce many of the parts at low cost and low profit so that the necessary investment for such operations was no burden on the Chrysler Co. For many years, Chrysler showed a larger percent of profit on investment than any other car manufacturer.

Dodge Brothers Pioneered

A public opinion poll would undoubtedly choose Henry Ford as the world's most successful automotive pioneer. But second place for individuals—with due regard for all the standards of pioneering, production, continuous and continual financial success, engineering achievements, improved foundry and machine shop practices—would probably find the brothers, **John and Horace Dodge**, in a tie.

The famous brothers operated one of the few machine shops in the Detroit area prior to 1900 when Detroit was known principally for timber, lumber, and woodworking operations. The Dodge brothers received \$10,000 in par value of the original Ford Co.'s stock, which they paid for through their shop services. They sold this stock to the Ford Co. in 1919, for \$25,000,000, after receiving \$10,000,000 in dividends. The dividends came as a result of a lawsuit against Ford for not paying dividends, which they won in 1917. After the Dodge brothers' untimely deaths in 1920, their estates' motorcar interests were purchased in 1924 by Dillon, Reed & Co. for \$152,000,000 in cash.

Ford Began at 40

The man who wrote the book, "Life Begins At Forty," could have used **Henry Ford** as his prime exhibit. Few people remember that his first business venture after spending his own money on homemade experimental models, was in the Detroit Automobile Co., which was the predecessor of the Cadillac Motor Car Co., the pioneer of all the General Motors divisions.

No other man had ever built up such a large

fortune in this country, and very few men have lived such an unremarkable life up to the age of 40, and then attained such prominence. The Federal Income Tax Law of 1914 guarantees that no American will ever duplicate his financial success.

Henry Ford lived on a farm in Dearborn until he was 17, and took his first job as a \$2.50-a-week machinist in Detroit in 1880. He probably worked 60 hours a week in the shop, but he worked for a jeweler at night and earned another \$2 per week. With board and room costing him \$3.50 a week, he had \$1 left, which he did not spend in riotous living.

After four years in Detroit, Ford returned to the farm. When he was 24, he returned to Detroit to work as engineer and machinist at \$45 per month, and eventually became chief engineer of the predecessor of the present Detroit Edison Co. With a salary of \$45 a month, he was able to save enough to carry on experiments, and in 1893, built and operated a steampowered car.

After his separation from the Detroit Automobile Co., he formed the Henry Ford Automobile Co. in 1901, with a capitalization of \$38,000—of which he received \$10,000 par value in exchange for his designs and inventions. In 1902, that company was dissolved because Henry Ford insisted that the production of a low-priced car was the best way to become a success in the motorcar field. In 1903, he, with 11 other stockholders, organized the present Ford Motor Co., with \$100,000 subscribed in fully paid stock, of which only \$28,000 represented cash. Among his stockholders were such names as Rackham, Couzens, Woodall, and Gray, all of whom became fabulously rich.

I vividly recall a visit to the Ford Motor Car Co.'s plant in Highland Park in 1914, when it had attained the record production of 100 cars per day. It was considered the world's greatest example of low-cost mass production.

It was most interesting at that time to ask which individual in the Ford organization was most responsible for the company's outstanding success—because the answers were so greatly influenced by each individual's business or professional activities. At that time, no Ford executive had a company title. The financiers gave most of the credit to **James Couzens**, who acted as treasurer, or to **Frank Klingensmith**, who acted as controller. The lawyers gave it to **C. G. Liebold**, who was Ford's attorney. Industrialists usually gave the credit to **Charles E. Sorensen**, who managed the factory, and had introduced the power-driven conveyor assembly line. Many steel producers and practically all metallurgists gave the credit to **Harold Wills**, Ford's pioneer metallurgist; and, at that time, the little known technology of metallurgy was classed with the arts of black magic. Engineers gave the credit to **William B. Mayo**, who acted as chief engineer; and sales experts gave the credit to **Norval Hawkins**, who was sales manager.

If anyone pointed out that Henry Ford had started the company bearing his name, and asked what he did, the usual answer was that Ford was a middle-aged man of very little education and very limited experience, who was nominal head of the company merely because he owned most of the stock.

In the following 10 years, all of the men mentioned, except Charles Sorensen, left the Ford Co.,

and with the exception of Senator Couzens, were seldom heard of again, and none ever became a notably successful motorcar executive. Harold Wills increased his reputation as metallurgist and designer in the production of his Wills car, but lost his investment through liquidation.

In the spring of 1920, following a year of post-war inflation accompanied by the wildest kind of commodity and stock market speculation, there was a market crash which wrecked many strong companies, especially in the automotive industry.

General Motors had hastily liquidated Durant's over-ambitious farm tractor program, and the Ford Co. appeared to be in desperate shape. The Wall Street bankers and brokers were convinced that the time had come when Henry Ford would be forced to come to them for aid in public financing. It was generally rumored that one of the first demands of Wall Street would be the removal of Ford as executive head of the business.

Ford Acts Decisively

It was only then that Ford's decisive action made all his detractors realize that he was a genius and not merely a lucky associate of geniuses. They still say that he knew nothing about accounting and that he had a narrow single-track mind. Be that as it may, he cut the price of his Model T, cleaned out his own high-priced inventory, and was the first to take advantage of the deflated prices offered by the various sources of supply who were anxious and willing to give their lowest prices to any crash survivor who seemed likely to build up big-volume business. In did not take Ford very long to build up new records in volume production.

SAE Personalities

The SAE had its origin in 1905, when there were 125 manufacturers, a few of whom were still producing steam and electric motorcars.

The first SAE president was **Andrew Riker** of the Locomobile Co. of America; the No. 2 membership went to Henry Ford; No. 3, to **John Wilkinson**, who designed the aircooled engine which powered the Franklin automobile; and No. 9 to **Col. Herbert W. Alden** of the Timken-Detroit Axle Co., who was the only engineer twice president. The Timken-Detroit Axle Co., now a division of the Rockwell Spring and

Axle Co., furnished another SAE president—**L. Ray Buckendale**.

Colonel Alden was my predecessor as chairman of the board of the Timken-Detroit Axle Co. He built a one-cylinder car in 1895, and, in December of 1900, made the first 500-mile non-stop run. He was the Timken-Detroit Axle Co.'s chief engineer for almost half a century, and was succeeded by Ray Buckendale.

At the 1952 meeting of Automobile Old Timers, I was seated next to **J. Frank Duryea** of the old Stevens-Duryea Motor Car Co.; and President **Charles E. Wilson** of General Motors, who was also at the speakers' table, asked me to reintroduce him to Duryea. Wilson said that he had not seen Duryea since his visit as a sales engineer around 1912 when he delivered a sample of a self-starter designed by the Westinghouse Co. I commented that it seemed to set a record for a sales engineer to make his second call after a 40-year interval.

Wilson went from Westinghouse to Remy Magneto Co., which later was merged with Delco, and both were merged with General Motors.

According to a rumor, Secretary of Defense Wilson was visited recently by one of the automobile manufacturers who has suffered great losses. The visitor asked Wilson if he could give any advice that would help. Wilson told of the time when the bankers insisted that General Motors must stop its losses, and the management decided that it would liquidate the Chevrolet division, which was showing the biggest loss. Wilson told his visitor that the management was so successful in the preliminary steps of liquidation that the Chevrolet division became very profitable, and, in the following years, attained first place in the production of low-priced automobiles.

Dynamic Past—and Future

Looking back from the early days of the automotive industry to the present, there is no doubt that it has been the most dynamic business in the history of the world.

To all who fear automation will cause unemployment, let us call attention to the simple fact that over 50% of our industrial employees are engaged in making products utterly unavailable to the common man, or beyond his purchasing power, just 60 years ago.

Air Transport Fleet . . .

. . . is inadequate for military needs. We must have more aircraft and new types, coupled with depots and communications network to form an integrated system.

Based on paper by **W. R. Rhoads**, Lockheed Aircraft Corp.

WE have fewer than 3000 airplanes for the movement of military cargo in an emergency. All are powered by reciprocating engines. The Military Air Transport Service has about 1000 cargo and passenger aircraft of which fewer than half are four-engined models. The Tactical Air Forces have about 600 transports. A small number are assigned to the

support of the Strategic Air Forces, while the Navy operates a few. The Civil Air Reserve Fleet, it is estimated, could supply some 400 transports with crews.

This fleet, made up of World War II and post-war types, is insufficient for even present day military needs. It performed incredible feats, helped shorten

the conflict, and saved billions of dollars and thousands of lives. After the war the fleet was allowed to deteriorate until the blockade of Berlin and the Korean War spurred action.

Three new types of aircraft are needed:

1. Cargo aircraft capable of vertical take-off and landing, to operate within a 600-nautical-mile radius for short haul within the industrial complex of the Zone of the Interior as well as in combat zones. Payloads of 10 tons or more would be desirable.

2. Airplanes capable of operation from short or hastily prepared strips, carrying payloads of approximately 25 tons, with ranges from 1500 to 3500 nautical miles for routes within the Z.I., from the Z.I. to overseas bases, and from overseas bases to combat zones.

3. Heavy duty cargo transports capable of carrying 50 to 100 tons for 4000 nautical miles or more.

These will have to be large and thus will require larger fixed base installations, making them extremely vulnerable to enemy attack.

Our air cargo fleet needs to be expanded to four or five times its present capacity and the cost of carrying cargo needs to be reduced. Coupled with this there is need to reconcile the difference between military and civil cargo aircraft requirements. Cargo transport should be completely integrated into the overall air logistic transport system and procedures evolved whereby the fleets may be operated alternately by the military or by commercial airlines as the military situation dictates. (Paper "Trends in Military Cargo Transport" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 20, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Better Brake Linings . . .

. . . may stem from research on frictional properties of minerals used for fillers. But development of linings is closely linked with trend in brake design.

Based on paper by **R. E. Spokes**, American Brake Shoe Co.

CONVENTIONAL automobile brake linings are frequently referred to as "organic," but their organic constituents seldom exceed 25%. The binders are organic and these together with certain friction-enhancing agents are subject to destructive distillation, the products of which are often lubricating. The changes may be only transient, but they can become progressive and permanent.

Metal-bonded linings represent a development to get rid of these organics. There are two types—the powder metal and the ceramic-metallic or cerametallic. They differ essentially in the amount of mineral filler and its grain size. Powdered or sintered metallics ordinarily contain about 8% by weight or 20% by volume of fine grain minerals, including those of ceramic character, in contrast to 24% by weight ceramic fillers or 50% by volume of large grain size for the ceramic-metallic. Both types are metal bonded.

Sintered metallics have had to be adapted to mechanisms and mating surfaces designed primarily for conventional molded liners. This has retarded adoption. The cost is high, particularly for the bronze base type. But with an iron base at 9½¢ per lb materials cost should be 2½ to 3¢ per cu in., or about the cost of conventional materials. If temperature relief is not afforded through forced cooling or change in brake design, we may have to turn to metal bonded liners.

The ceramic-metallic type has been very successful in certain aircraft brake applications, outwearing the best organic bonded liners four to one, but that doesn't mean that it is ideal for automobile brakes. The segments are brittle and the wear prop-

erties exhibited at high temperatures are not available at lower automobile temperatures. In fact, little improvement is shown over organic-bonded liners and adverse drum wear is common.

Much can be gained from experience acquired in improving liners for heavy duty application. Marked changes have been made in composition, resulting in more heat resistance. Further improvement will come through choice of minerals.

The newer mineral materials exhibit wide differences in their frictional properties and many have a marked effect in counteracting the lubricating fractions from bond deterioration. They will replace less heat resistant asbestos to a point where it will be used solely as a reinforcing fiber rather than as the principal mineral constituent.

Many minerals used as fillers and selected for their friction-enhancing action have been chosen solely for their hardness. But they possess many more characteristics which could enhance friction such as interface pressure and favorable crystallographic properties and particle configuration. The correlation of these with friction phenomena warrants research. More, too, should be known about correlation of friction phenomena with the physical properties of the matrix imbedding these minerals if full advantage is to be had from these new minerals.

(Paper "New Lining Materials" was presented at SAE Golden Anniversary Passenger Car, Body & Materials Meeting, Detroit, March 3, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

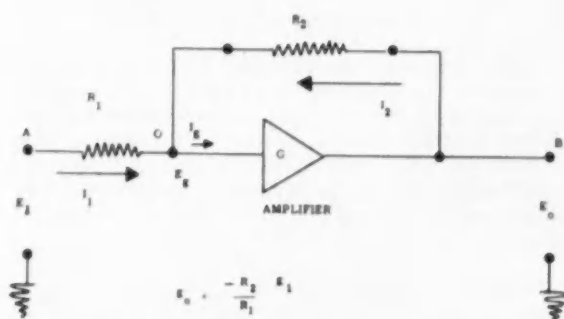


Fig. 1—Computer can be set up this way for multiplication by a constant. R_2 is twice R_1 , therefore E_0 is twice E_1 .

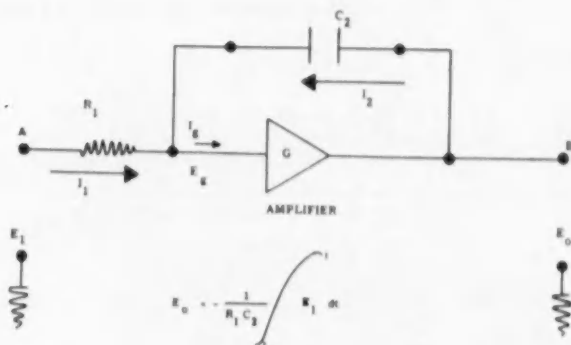


Fig. 2—For integration, the voltage E_0 across C_2 increases at a constant rate, hence E_0 is the integral of E_1 .

How An Analog Computer Works

Thomas Wood, Research and Development Division, Detroit Arsenal

Based on paper "The Use of Analog Computers in Design of Military Vehicles," presented at SAE Automotive Ordnance Day, Detroit Arsenal, Center Line, Mich., Feb. 28, 1955.

THE ANALOG computer is an electronic instrument capable of solving mathematical equations at high speed. It works on the principle that electrical systems of capacitances, inductances, voltage, and current can be set up in a manner analogous to the equations.

The more frequent fundamental operations performed by analog computers are:

1. Multiplication by a constant.
2. Integration of quantities with respect to time.
3. Multiplication of variables.

The basic building block of the computer is the operational amplifier. It performs various operations depending upon the impedances that are placed in the feedback and input circuits of the amplifier. All physical parameters are expressed by voltages.

To illustrate the method by which the operational amplifier functions as a multiplier, let's assume, in

Fig. 1, that the gain, G , of the amplifier approaches infinity.

To get finite voltage out of the amplifier at B we must not have any voltage at point O ; hence E_0 will be zero. (In practice we may use a gain about 200,000, which makes E_0 not zero but negligible.) By placing resistors R_2 and R_1 in the feedback and input circuits, the amplifier is "patched" for multiplication. For example, to multiply by two, we place a one megohm resistor in the feedback, and a 0.5-megohm resistor in the input. Any voltage E_1 impressed at A across the input resistor R_1 will cause a current I_1 to flow in the input circuit. Kirchhoff's law states that the algebraic sum of the currents that meet at any junction is zero. So, $I_1 + I_2 + I_0$ must equal zero. I_0 is the current drawn by the grid of the operational amplifier and is about 10^{-10} amp, therefore negligible. Thus I_2 must be equal and opposite in sign to I_1 to make the sum equal to zero. This produces a sign change across the amplifier and will induce voltage E_0 which is of opposite sign and

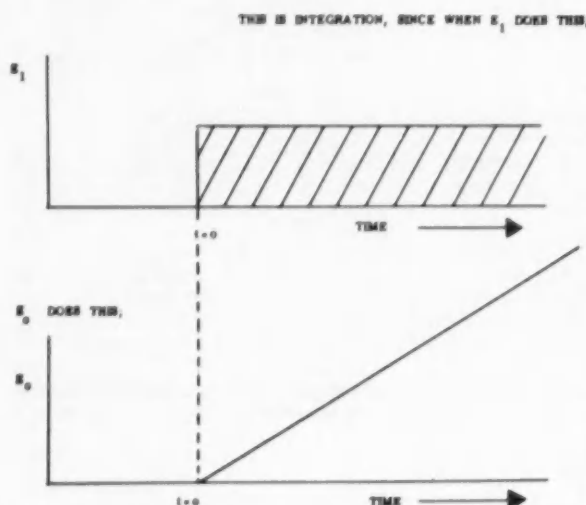


Fig. 3—The output voltage is a measure of the area under (integral of) the input voltage curve.

twice E_1 . This is true because I_2 is equal to I_1 and R_2 is twice R_1 . Hence E_0 is twice E_1 .

To multiply by any constant, it is necessary to select the appropriate R_2 . (R_2 is usually kept at 1 megohm.)

Fig. 2 illustrates the method of "patching" the operational amplifier for use as an integrator.

By placing a 1-megohm resistor in the input circuit (R_1) and a one microfarad capacitor (C_2) in the feedback circuit, the operational amplifier will generate the time integral of the input voltage E_1 . The voltage at A, called E_1 , produces a current I_1 to flow through resistor R_1 . So, to satisfy Kirchhoff's law that the algebraic sum of the currents which meet at any junction is zero, I_2 must be equal and opposite in sign to I_1 . To produce this current I_2 the voltage E_0 across C_2 must be increasing at a con-

stant rate; hence E_0 is the integral of E_1 .

Fig. 3 shows that the slope of E_0 is dependent upon the ratio of C_2 and R_1 . Therefore, we can both integrate and multiply by a constant with this arrangement.

Multiplication of two variables can be performed by means of a servo system. In Fig. 4, the variable E_1 produces an output shaft motion whose angular position varies with time exactly as E_1 . The output shaft controls the position of the arm of a potentiometer across which the variable E_2 is applied. The voltage on the arm is a fractional part of the applied voltage E_2 , or $E_0 = E_1 E_2$.

Analyzing suspension systems

The analog computer is particularly useful in analyzing automotive suspension systems. It works on the analogy between the electrical behavior of a capacitance-inductance system and the mechanical behavior of a spring-mass system. (Work at the Battelle Memorial Institute applying an analog computer to automotive suspension problems is described in the article, "Analog Helps Solve Suspension Problems," by Dr. Horace Grover, in the April 1955 issue of the SAE JOURNAL.)

It makes it possible to determine the feasibility of a design without constructing expensive models and conducting extensive, often destructive, laboratory tests. Also, it helps the engineer determine the design principles which offer the most promising avenues of investigation. In cases where the values of parameters are uncertain the computer aids in defining the limits in which the parameters can vary and produce satisfactory results. This is extremely valuable in establishing tolerances on vehicle parts, and prevents the costly manufacture of unnecessary precision parts.

The analog solves numerous simultaneous second-order equations which result from isolating each component of the suspension system. The effectiveness of the computer depends on the completeness and the validity of the data fed into it. In analyzing a radically new suspension system, this information may be incomplete and will require extensive extrapolation. In this case, the computer will determine qualitatively the manner in which each design variable affects the system's performance. The simulation will indicate the design of the system which has optimum characteristics, but will not provide an absolute measure of performance.

While it is true that analog computers will save an enormous amount of time and money which normally would be spent in construction cost and laboratory tests, much more could be accomplished if more engineers were adept in correlating the physical reaction of structures in terms of graphical data. A new "simuscope" which presents a reproduction to scale of the motion of the chassis and wheels as the vehicle goes over an obstacle at different speeds has helped this problem.

It can be expected that as engineers become aware of the numerous uses of the analog they will begin to use it to fuller advantage in much wider applications.

(Paper on which this abridgment is based is available in full, in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

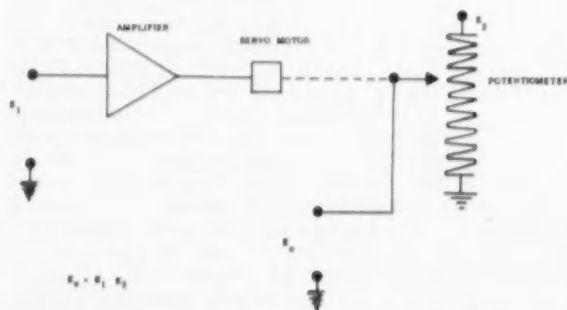


Fig. 4—To multiply two variables a servo motor controls the position of the arm of a potentiometer across which the variable E_2 is applied. Other variable, E_1 , controls the servo motor.



HELIPORT DESIGN FOR A MAJOR CITY OF THE FUTURE

HELIPORT SITES...

... must take into consideration noise, safety, and accessibility.

SEVERAL studies have established criteria for the selection of helicopter airports near big cities.

- First of all, it must be accessible to vehicle traffic.
- It must be near a Post Office since mail revenue will be of major importance.
- An elevation of three or four stories seems preferable.
- Approach area must permit emergency landings, and be able to withstand noise and rotor blast.
- Fuel storage must be accommodated.
- Location must be clear of obstacles, and guaranteed by zoning or through natural means such as overwater approaches.

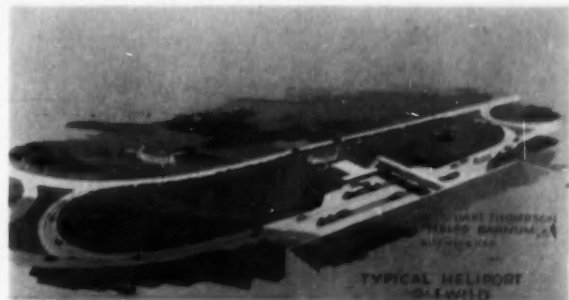
Of course, the cost of developing the site must be low enough to encourage a young industry.

Paper **On the Location of Heliports** by **HORACE BROCK**, New York Airways, Inc., was presented at the SAE Golden Anniversary Aeronautic Meeting, New York, April 20, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.



Above: Port of New York Authority Heliport

Below: Heliport Design for major airport



High-Speed Photos Reveal How End Gas

HIGH-SPEED photographs of the combustion process in an engine equipped with a quartz window in the cylinder head indicate that:

1. A cool-flame reaction does exist in an engine.
2. The cool flame may be propagated at a relatively high rate.
3. Autoignition may occur after the cool flame forms.
4. When knock occurs under the operating conditions of the test with the fuel that was used, a

reaction appears in the end gas, distinct from the spark-ignited flame.

5. The knocking reaction consumes the end gas at a moderately high rate.

6. The spark-ignited flame does not accelerate into the end-gas region.

7. There is no positive evidence of a cool flame in knocking combustion, but this lack of evidence certainly does not exclude the possibility of the existence of a cool flame in this type of combustion.

8. The knocking reaction is accompanied by a rapid rise in cylinder pressure producing an acoustic resonance in the gases.

Table 1—Engine Operating Conditions for Study of Cool Flames

Engine Speed (Approx.), rpm	600
Manifold Pressure, in. Hg	27
Carburetor Air Temperature, F	80
Cylinder Jacket Coolant Temperature, F	190
Head Coolant Temperature, F	50
Oil Temperature, F	< 100
Ignition	None
Compression Ratio	7/1

Cool Flames

The first three of the conclusions are based on photographs taken at 7200 frames per sec of an engine autoigniting on a very lean (25/1 air/fuel ratio) mixture of *n*-heptane. Engine conditions are given in Table 1. Under these conditions the cool flame is well separated in time from the subsequent hot flame, so that the two stages of the combustion process are distinct. It was convenient to include the hot-flame reaction since the heat of the reaction helped maintain the engine temperatures required to stabilize the cool flame.

Fig. 1 diagrammatically shows a typical frame from the high-speed film containing the shadowgraph image (obtained by directing a point source of light at the piston top, which was provided with a mirror surface) and a projected image of the flywheel timing marks. The direct photographic image is eliminated from the cool-flame series since the light from these flames is insufficient to expose the films. The flywheel is numbered every 10 deg from 0 deg at top center with a spot identifying the 5 deg graduations from individual degree marks. The optical system frequently obscured the final zero on the flywheel numbers so that the number 35 would correspond to the 350-deg mark.

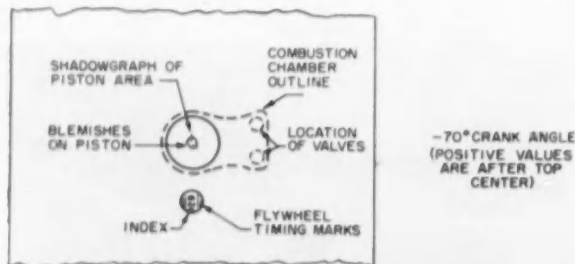


Fig. 1—Explanation of individual frames of shadowgraph

Lives — and Dies

George A. Ball, Ethyl Corp.

Excerpts from paper, "A Quick Look at Engine Combustion," presented at SAE National Fuels & Lubricants Meeting, Tulsa, Nov. 5, 1954.

Fig. 2 shows selected frames from a typical sequence of the cool-flame cycle. It is immediately obvious that the reproductions of the individual frames show no clearly defined flame front, particularly of the cool-flame reaction. When the films are projected, however, it is possible to detect an indication of an orderly progression of the reaction. Furthermore, if the reaction is viewed directly in the engine through a stroboscopic disc, the existence of a flame front is apparent even though the radiation from the flame is close to the limit of visibility. Consequently, the following description of the phenomena represented by Fig. 2 is based in part on direct visual observations.

The cool-flame reaction initiates at the valve end of the combustion chamber. Since no spark is occurring in the engine, the onset of the cool flame is presumably due to a local source of heat somewhere in the neighborhood of the valves and the spark plug. The reaction passes across the combustion chamber and terminates at the far end of the chamber over the piston. Following a path similar to the cool flame, the hot flame also originates spontaneously in the valve area and travels the length of the chamber.

Frames 1 to 5 of Fig. 2 show the gradual mottling due to turbulence prior to the cool flame. Frames 6 to 19 show the increased mottling in the region

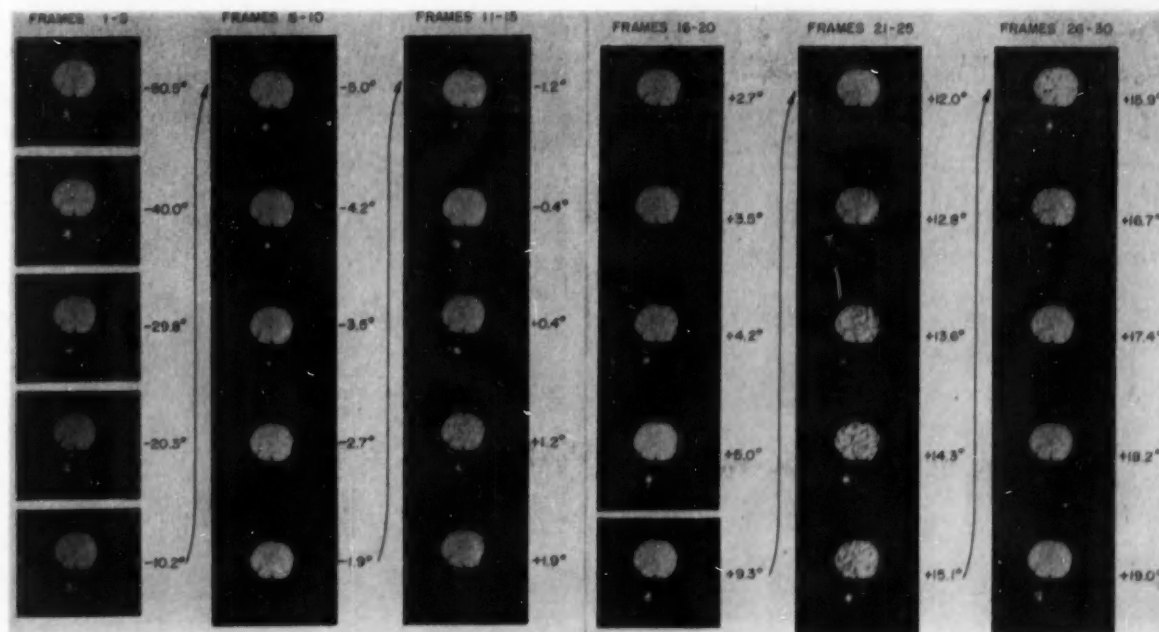


Fig. 2—Individual frames showing mottling due to cool flame and autoignition

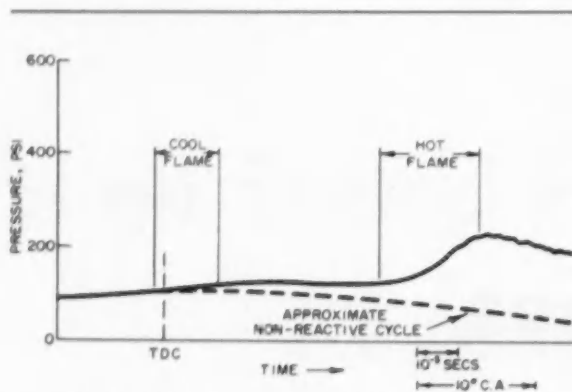


Fig. 3—Pressure increase due to cool and hot flames

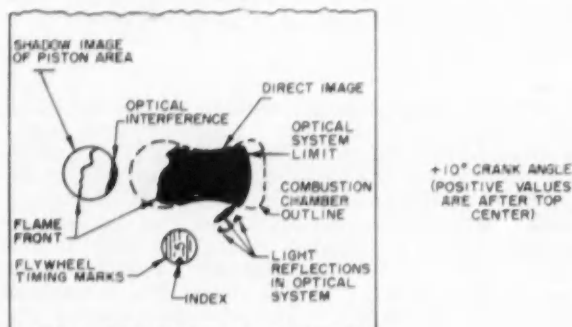


Fig. 4—Explanation of individual frames of simultaneous direct and shadow images

of the cool flame. The cool flame actually occurs during about six frames around top dead center. Frame 20 illustrates the interim between the cool flame and hot flame. Frames 21 to 25 show the hot flame as greatly increased mottling, which then decays in the remaining frames. The time of transit across the chamber for flames similar to those shown here has been estimated to be about one-quarter that of a normal spark-ignited flame, the estimation being based on visual observations made with the stroboscope.

Fig. 3 shows the pressure record of a similar cool-flame cycle, illustrating the heat release during the cool-flame period followed by the rapid release of heat by the hot flame. The combustion process was plainly audible, as is indicated by the pressure fluctuations following the passage of the hot flame.

Knocking Combustion

The remainder of the conclusions are based on high-speed photographs taken in the engine during knocking conditions. The fuel—90% 2, 2, 4-trimethylpentane + 10% *n*-heptane—was burned at a 14/1 air/fuel ratio. Table 2 details engine operating conditions.

Fig. 4 illustrates a typical frame from the knocking sequence shown in Fig. 5. Prior to frame 1, the flame has developed normally and continues to do so until frame 14. This frame shows the start of a reaction which passes through the end gas in the next four frames. The shadowgraph image in frame 16 shows that a large part of the spark-ignited flame retains its character during this reaction in the end gas. It appears that the spark-ignited flame does not accelerate into the end gas during this phase; in fact, when the films are pro-

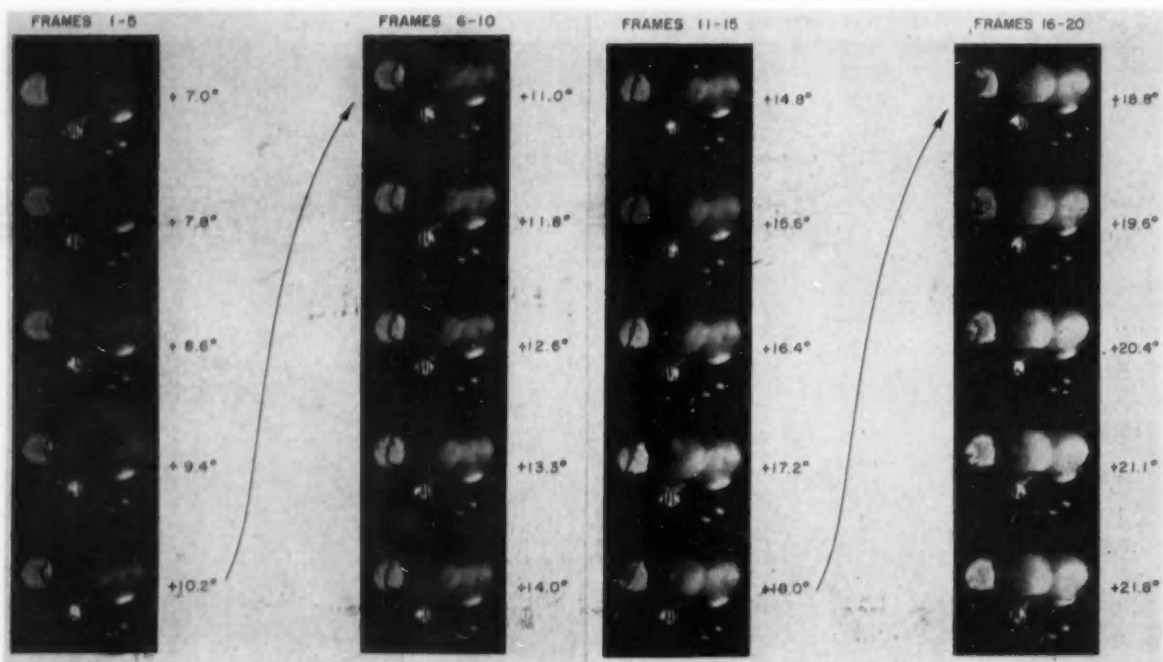


Fig. 5—Individual frames showing direct and shadow images of knocking combustion

Table 2—Engine Operating Conditions for Study of Knocking Combustion

Engine Speed, rpm	600
Manifold Pressure, in. Hg	29
Carburetor Air Temperature, F	80
Cylinder Jacket Coolant Temperature, F	190
Head Coolant Temperature, F	50
Oil Temperature, F	< 100
Ignition Timing (Approx.), deg	20
Compression Ratio	7/1

jected as motion pictures, there is a definite impression that the spark-ignited flame is even reversed in its travel through the chamber by the rapid burning of the end gas.

If the reaction in the end gas can be considered as a flame with a velocity of propagation, then this velocity is of the order of several hundred feet per second, but certainly not as high as a thousand feet per second. Therefore this phenomenon is not a detonation wave in the sense of a supersonic combustion wave accompanied by a shock wave. Thus we have two subsonic phenomena, the spark-ignited flame and the spontaneous reaction, simultaneously consuming the same small volume of a combustible gas. It should be noted that there is no positive indication of a cool flame in the end gas.

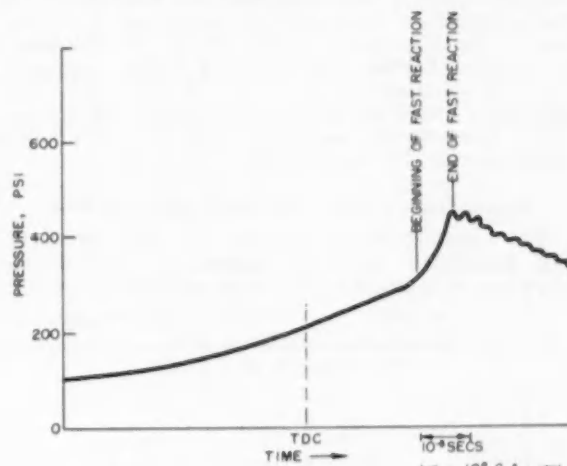


Fig. 6—Pressure trace showing knocking combustion

Fig. 6 shows a pressure record taken from a similar knocking cycle. Pressure development proceeds normally as the flame burns, until a steep rise in pressure occurs, which corresponds precisely with the time of the reaction in the end gas.

(Paper on which this abridgment is based is available in full in photoffset form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

EXCERPTS FROM DISCUSSION

How Cool Flames Travel

—J. E. Getz

Purdue University and Standard Oil Co. (Ind.)

THE author points out that cool flames did not show in his photographs because their radiation is of low intensity. In our investigations at Purdue with an engine cylinder and quartz window of the same design as the author's, a photomultiplier tube served as the radiation detector of cool flames because this type of detector has a sensitivity far exceeding that of photographic film. Fig. A is a typical oscilloscope record of flame radiation from a small portion of the combustion chamber during an individual combustion cycle. The appearance of the cool flame is considered as the time when there is a detectable deviation from the base line. The intensity of light emission from cool flames (shown by the small hump) is so much lower than that from hot flames (shown by the line extending

upward) that it is not likely that it would affect film exposed at the rate the author employed (up to 7200 frames per sec).

Cool-Flame Movement

Photomultiplier tube data on the appearance of cool flames from a blend of 30% *n*-heptane and 70% toluene are presented in Fig. B. Engine operating conditions are given in Table A. Each point is an average of about 35 combustion cycles. The curves show that the cool flames appear to move gradually from the valve area to the piston area. This apparent movement is very pronounced for the low mixture temperature and is less pronounced for each higher temperature, until at 335 F the cool flame starts to appear throughout the combustion chamber during a short period of time. The results at low mixture temperature corroborate the author's visual observation that there was a pronounced movement of the cool flame, with the reaction starting in the neighborhood of the valves (prob-

ably due to their high temperature), passing across the combustion chamber, and terminating at the end of the chamber over the piston. In the work at Purdue higher temperatures gave less pronounced evidence of movement. If intake air temperatures above 80 F had been used, the author might have found less pronounced but more rapid movement of the cool flames.

Propagation versus Progressive Autoignition

The question arises whether this movement of the cool-flame reaction across the combustion chamber is a propagation or a progressive occur-

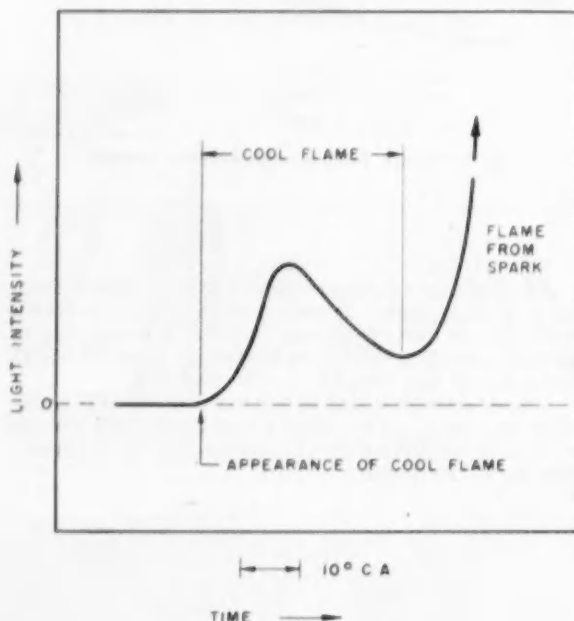


Fig. A—Cool-flame radiation

Table A—Engine Operating Conditions (Getz)

Engine Speed, rpm	900
Manifold Pressure, in. Hg	29
Air/Fuel Ratio	13/1
Spark Timing, deg after tdc	20

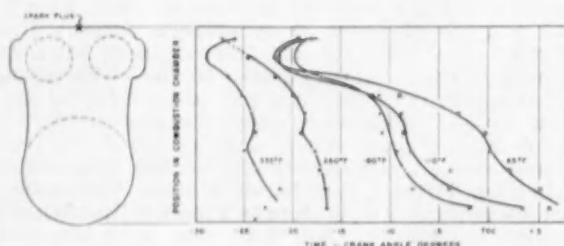


Fig. B—Appearance of cool flame for various mixture temperatures

rence of the conditions (such as temperature) necessary for the appearance of a cool flame. Fig. B reveals that the movement of the cool-flame reaction is a combination of the aforementioned phenomena. Each curve for a high mixture temperature has a slight reversal or "knee" about halfway across the chamber. The knee was also found using other fuels; for a blend of 40% *n*-hexane and 60% toluene and a blend of 50% *n*-pentane and 50% toluene it was even more prominent than for the 30% *n*-heptane, 70% toluene blend which is illustrated. This knee indicates that the cool-flame velocity (in the direction from valves to piston) is negative for a short distance. Since negative propagation is not reasonable, the knees indicate that propagation is not the sole mechanism causing successive appearance of cool flames. The knees can best be explained by assuming that certain portions of the gas mixture in the combustion chamber attain the necessary pressure and temperature for the formation of a cool flame before other portions of the mixture, for example, in the case of unequal temperature distribution in a combustion chamber. Surrounding portions of gas mixture successively attain the necessary conditions for formation of a cool flame. Thus, the cool-flame movement across the combustion chamber may be very rapid. The high-mixture-temperature curve of Fig. B indicates an apparent flame speed of about two to seven times the flame speed of normal combustion. This, too, is best explained on the basis of the successive occurrence of the conditions yielding cool flames rather than on the basis of propagation of the reaction.

Although the data for the 335 F mixture suggest cool-flame movement by successive occurrence of proper conditions rather than by propagation, the data for the 65 F mixture suggest propagation of cool flames. The curve for the 65 F mixture shows a slow and pronounced movement of the appearance of the cool flame at about the same speed as normal combustion. This movement cannot be explained on the basis of succeeding occurrence of the conditions necessary for cool flames. With the 65 F mixture, cool flames appear at tdc, whereas with the 335 F mixture they appear about 25 deg bte. The piston movement near top center is very small and there would be little change in temperature due to compression by the piston. Also, the appearance of the cool flame continued to progress across the combustion chamber after top center (as late as 13 deg for individual cycles). The temperature distribution across the combustion chamber due to heat transfer from the walls to the gas could not be the factor responsible for this movement of the appearance of the cool flame because the combustion chamber is wedge-shaped, with the tapered end over the piston. Heat conducted from the wall would cause the gas over the piston to become heated sooner than the gas near the center of the chamber. This would cause cool-flame movement to be in the opposite direction.

The possibility that a cool flame could form in the valve portion of the combustion chamber and then be swept by turbulence over the piston and appear as cool-flame propagation under the field of the phototube viewer should be considered. If highly turbulent conditions prevailed, luminous gas

moving indiscriminately in front of the phototube detector would give the appearance of more than one cool flame. Only a small number of traces observed showed evidence of more than one cool flame; so, turbulence could not entirely account for the continued movement of the cool flame after top center. The only tenable explanation for the movement with the 65 F mixture would be a propagation of the cool flame. This propagation would entail any or all of the following factors: (a) the conduction of thermal energy in the vicinity of the cool-flame front to the nonluminescent gas, (b) the transfer of radiant energy from the cool-flame front to the nonluminescent gas (this would be almost negligible), (c) the transfer of free radicals or molecules from the cool-flame front to the nonluminescent gas.

From the evidence given in Fig. B, it appears that the movement of the appearance of cool flames in an engine cylinder is a combination of propagation and a progressive occurrence of the conditions necessary for the formation of a cool flame.

More Data on Cool Flames

J. T. Wentworth and W. A. Daniel

GM Research Laboratories

In our tests we used the photomultiplier tube detector in conjunction with a steel head provided with a quartz window. The window was placed so that the end-gas region of the combustion chamber could be viewed in a direction perpendicular to the propagation of the normal flame. The engine conditions are given in Table B. The fuel used was 88-octane-number primary reference blend. Borderline spark timing was about 4 deg atc; thus, the engine was knocking at these conditions.

In Fig. C are shown four radiation intensity-time oscilloscope traces and three pressure records. The pressure records were obtained with a condenser-type indicator. Four radiation traces are shown, each at a different oscilloscope amplification, in order to record the wide range of radiation intensities present in the engine. The four radiation traces and the three pressure records were not obtained for identical cycles and some cyclic variation was present. In the lower radiation trace with a relative amplification of one, the peak radiation from the knocking flame saturated the amplifier, causing a plateau effect (starting at about 30 deg atc). In the second radiation trace from the bottom with a relative amplification of 10, the knocking flame portion of the radiation trace is off scale and the cool-flame radiation is just detectable around tdc. In the third radiation trace with a relative amplification of 100, the radiation from the cool flame is clearly shown. Finally, in the top trace with a relative amplification of 1000, only the initial

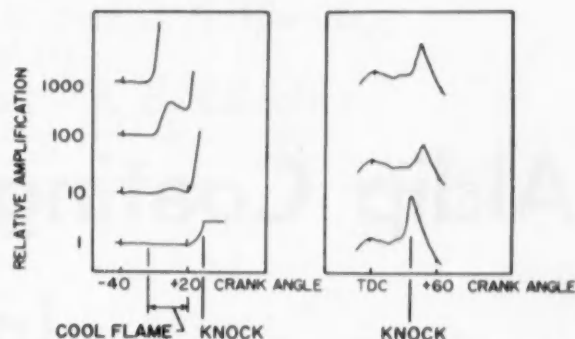


Fig. C—End gas radiation traces (left) and pressure records (right) obtained during knocking combustion

Table B—Engine Operating Conditions
(Wentworth-Daniel)

Speed, rpm	900
Manifold Pressure, in. Hg (abs.)	34
Spark Timing, deg atc	2
Air/Fuel Ratio	13.4
Inlet Mixture Temperature, F	75
Coolant Temperature, F	212
Compression Ratio	8.6/1

tion of the cool-flame portion of the radiation trace is shown. Thus, cool-flame radiation has been observed in a knocking combustion cycle.

The spark timing, manifold pressure, and air/fuel ratio were successively changed from the values listed previously to obtain nonknocking engine operation. It was found that cool-flame radiation could be observed in these nonknocking combustion cycles, but also, if the air/fuel ratio were sufficiently rich (about 9.4), cool-flame radiation was not detected. By advancing the spark timing with a rich air/fuel ratio, knock was obtained; but the cool-flame radiation was still not observed at the highest amplification available. Thus, it would seem that cool-flame radiation is not a prerequisite for knock.

Under all conditions investigated radiation of intermediate intensity was observed in the end gas just prior to knock or to the arrival of the normal flame. The source of this radiation of intermediate intensity is unknown. Although the possibility of its being reflected light from the normal flame has not been eliminated, there is some evidence that the intermediate radiation is not reflected light. In addition the intermediate radiation may be related to the second flame front observed in the author's motion picture sequence of knocking combustion and/or it may be related to the blue flame reported by Sturgis.³ In any event, the lack of correlation in our work between the occurrence of knock and the presence of a cool flame in the end gas is specifically restricted to the relationship between radiation occurring before the intermediate radiation becomes evident and the occurrence of knock.

³ "Some Concepts of Knock and Antiknock Action," by B. M. Sturgis. Paper presented at SAE National West Coast Meeting, Los Angeles, Aug. 18, 1954. It will be published in full in the 1955 SAE Transactions.

Aldip Coating

Improves Valve

COATING engine intake and exhaust valves with aluminum improves their durability. One technique, General Motors' *Aldip* process, provides a smooth, thin coating of aluminum without distorting the valve, if it is stress-relief annealed or relatively free from straightening stresses. A year's production experience at Pontiac Motor Division indicates that the treatment is commercially feasible and very beneficial to valve life.

The Aldip process

Valves are *Aldip* processed after the seats have been finish machined and the stems rough ground. Essentially, the process used at the Pontiac plant consists of dipping about 1 in. of the head end of the valve into a molten flux bath, followed by dipping it into molten aluminum. Then the valve is held in a fixture while compressed air removes the sur-

plus molten aluminum from the valve seat. Fig. 1 is a sketch illustrating these steps.

More specifically, the processing steps are as follows:

1. Valves are cleaned by vapor degreasing prior to being placed in a fixture which holds eight valves.
2. Fixture is placed on a conveyor rack.
3. Head end of valves are automatically immersed in molten flux at 1325 F. Flux is composed of 40% sodium chloride, 40% potassium chloride, 10% sodium aluminum fluoride, and 10% aluminum fluoride.
4. Valves are automatically conveyed through a furnace to a pot containing commercial 25 aluminum. This takes 3 min.

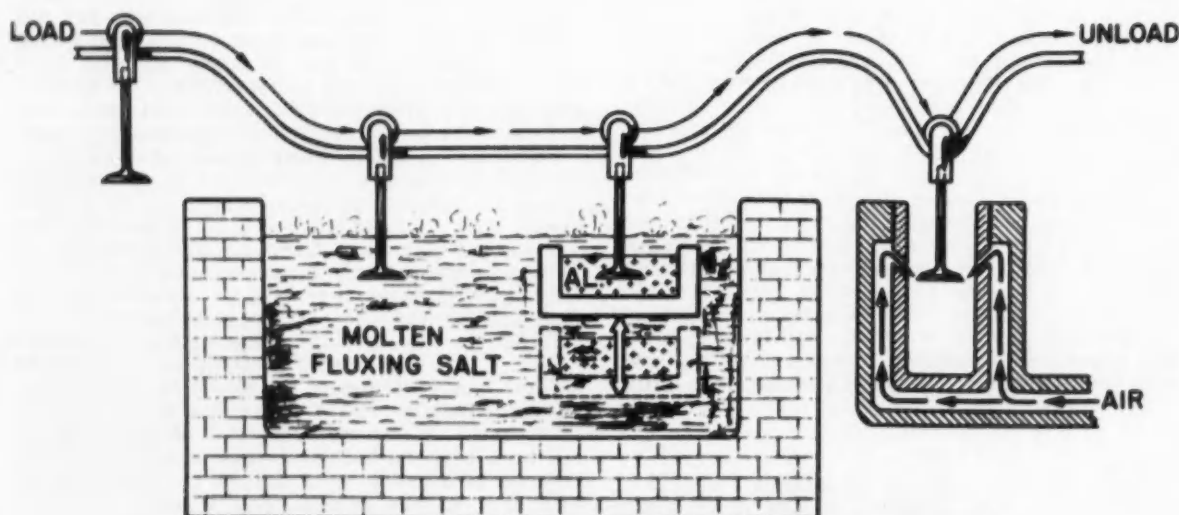


Fig. 1—The *Aldip* process, schematically illustrated above, has been used by Pontiac for over a year.

R. F. Thomson and D. K. Hanink,

Research Laboratories Division, GMC

E. B. Etchells,

Chevrolet Motor Division, CMC

K. B. Valentine,

Pontiac Motor Division, CMC

Based on paper "Engine Valves Improved by Aldip Coating," presented at SAE Golden Anniversary Annual Meeting, Detroit, Jan. 14, 1955.

Durability

5. The aluminum pot rises, immersing the valve head in aluminum for 5 sec.
6. The aluminum pot is lowered.
7. Valves are immediately removed from the furnace and positioned in a blow-off machine.
8. Compressed air removes surplus aluminum from the valve seat face.

Fig. 2 shows valves processed by this method. Two distinctly different conditions can be produced depending upon how metallurgically clean the surface is.

Processing costs may be appreciably reduced and the production rate increased by applying the aluminum to the valves before immersing in the molten salt bath. This may be done in a number of ways:

1. The aluminum may be applied as a paste by mixing aluminum powder with a suitable binder.
2. The aluminum may be metal-sprayed onto the article to be coated.
3. The aluminum may be applied in the form of aluminum powder (suspended in a suitable vehicle) which is sprayed onto the article to be coated.
4. The aluminum may be applied in the form of a washer or as a wire ring set on the valve head.

Figs. 3 and 4 show micrographs of the type coating produced on the intake and exhaust valve steels. There is a slight aluminum overlay. Underneath is an iron-aluminum alloy layer which provides the resistant properties.

The thickness of the alloy layer changes for several valve steels as shown in Fig. 5.

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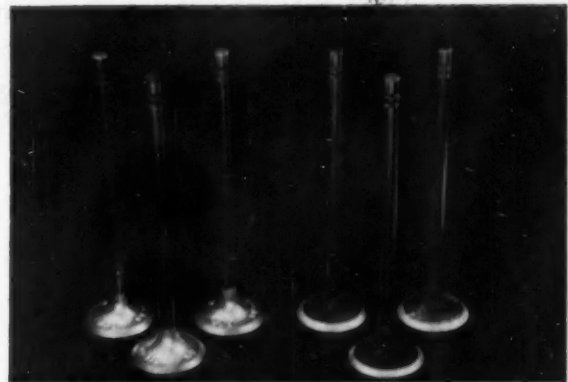


Fig. 2—Valves on the left were coated with the entire head metallurgically clean. Those on the right were clean only on the valve seat. Both methods produce satisfactory valves.

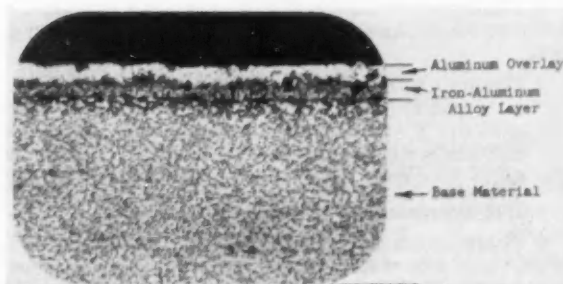


Fig. 3—This is a micrograph, magnified 500 times, of an Aldip-coated XB exhaust valve. Valve is made of silchrome XB which consists of 0.60-0.85% carbon, 0.20-0.60% manganese, 1.25-2.75% silicon, 19.00-23.00% chromium, and 1.00-2.00% nickel.

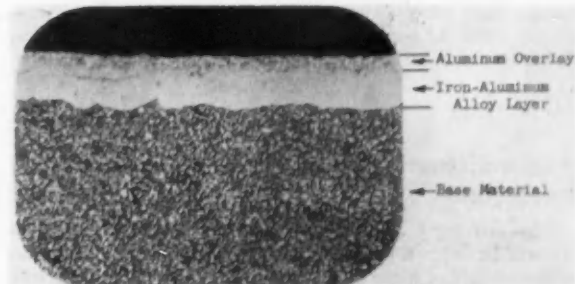


Fig. 4—This is a micrograph, magnified 500 times, of an Aldip-coated GM 8440 intake valve. Analysis of GM 8440 is: 0.35-0.45% carbon, 0.25-0.40% manganese, 3.60-4.20% silicon, 1.85-2.50% chromium. The iron-aluminum layer provides resistant properties.

For further information about **Aldip** see "Coating Steel by the Aldip Process" by D. K. Hanink and A. L. Boegehold, in the April, 1953 issue of **SAE Journal**.

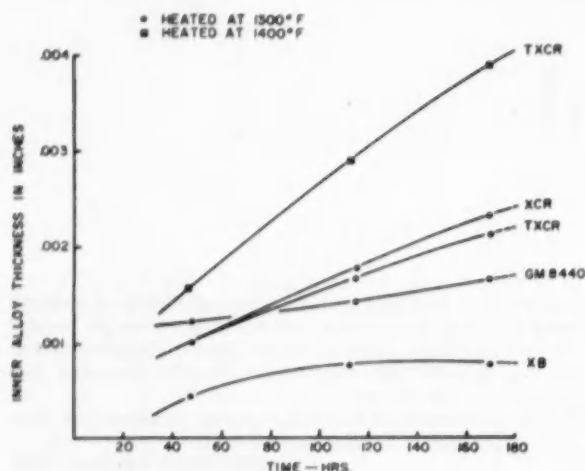


Fig. 5—The thickness of the inner iron-aluminum alloy layer changes with time for several Aldip-coated valve steels when heated at 1300 and 1400 F.

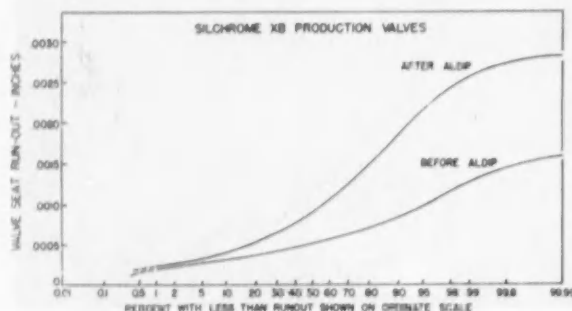


Fig. 6—The effect of Aldip coating on valve seat run-out is shown above. Run-out measurement is the total indicator reading on the seat in relation to the valve stem when rotating the valve about the axis of the stem. If 0.0015 in. run-out is allowed for the Aldip operation, nearly 100% of the valves will fall within a blueprint tolerance of 0.003 in., provided the valves had been stress-relieved after straightening.

Valve distortion during Aldip process is not excessive

The amount of distortion after Aldip coating is shown in Fig. 6 for XB valves which were stress-relieved after straightening. If the valves are not stress-relieved the amount of distortion occurring during the Aldip operation depends on the amount of stress remaining in the valve due to the straightening operations.

Table 1—Controlled Accelerated Car Performance Test Summary

Kind Valves	Number of Engines Tested	Exhaust Valves			
		No. Burned Valves	Total Mileage All Engines	Earliest Failure Miles	Maximum Life Without Failure*
Aldip	10	3	286,162	14,203	51,040
Uncoated	8	21	157,295	3,145	37,909

Kind Valves	Number of Engines Tested	Intake Valves			
		No. Burned Valves	Total Mileage All Engines	Earliest Failure Miles	Maximum Life Without Failure*
Aldip	10	0	286,162	None	51,040
Uncoated	9	37	165,189	2,695	37,909

* Could be operated after this mileage.

Aldip coated valves are more durable

Tests of valves in the laboratory and in the field indicate that Aldip treatment will increase the durability of XB exhaust and GM 8440 intake valves by at least 100% under certain engine design conditions. In a series of three tests, only two of nine Aldip coated valves failed, whereas nine original and eight replacement uncoated valves burned and failed.

Field tests using four Aldip-coated valves and four uncoated valves in a heavy-duty, 2-ton truck engine found that all four uncoated valves "burned" and none of the Aldip-coated valves failed.

Eighteen test cars, 10 having engines equipped with Aldip-treated valves and eight having engines equipped with plain valves were operated under accelerated test conditions for various mileages up to 51,040 miles. A summary of data obtained for the exhaust and intake valves are shown in Table 1.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Based on discussion . . .

The following specific facts were brought out during the general discussion following the paper's presentation:

- Thompson Products Co. Inc. has an automatic Aldip process capable of producing 3600 valves per hour.

- The temperature of the bath, the volume of the valve that is heated, and the time of the valve in the bath are just a few of the items that influence the distortion (run-out) that can be attributed to the Aldip process.

- The aluminum penetrates to a depth of 0.001 in.

- There is an increase in carbon concentration below the iron-aluminum layer, but there is no noticeable effect on performance.

- There are four variations of the Aldip process of putting aluminum on the valve face. Aluminum can also be put on the valve prior to dipping.

Experience Teaches

How to Form Titanium

J. M. Ohlson, Rohr Aircraft Corp.

Based on secretary's report of the panel on Forming of the SAE Aircraft Production Forum, Los Angeles, Oct. 5, 1954.

TRICKY as titanium still seems, we've learned a lot about forming it in the relatively short time we've been working with it.

Where once the scrap rate on titanium parts ran as high as 250%, two large West Coast users now find their rates are 12-15%. This low figure includes workmen's errors as well as defects attributable to the material. In other words, titanium is scrapped only slightly more than other aircraft metals in these two shops.

Here are some of the findings of these two companies and other titanium users:

Materials As Received—Titanium currently does not possess the quality and uniformity of other commercial metals. It requires inspection on receipt. Users test all sheets by some means such as bend tests, tensile tests, tear tests, and dimple tests.

One company finds much difficulty with "canned" material which is not flat enough for exterior skins. They point out that this material is made on a hand mill and that ripples and cans are prevalent. To overcome this, they have had to stress relieve the sheets in fixtures prior to any other operations. This is done by taking two 1½-in. plates of cold rolled steel and grinding or machining one surface on each perfectly flat. Six to 10 sheets of titanium are then placed between the steel plates and clamped with a large U clamp. They are placed in a car bottom or steel heat-treat draw furnace set at 1050 F. It is necessary to keep the titanium in the furnace long enough for it to reach at least 800 F. This produces fairly flat material.

Some other users perform a similar operation, interleaving the sheets with paper to prevent scratches.

Cutting—Titanium cannot be cut with ordinary cutting tools and then formed. It is very susceptible to edge cracking. Many times all edges are smoothed with a vixen file. In other cases, several straight parts have been set up on a mill and gang milled. Friction sawing at 14,000 fpm has proved fairly successful on up to ¼-in. thick material. Electrical high frequency cutting has not proved really successful. On bar stock, a silicon-carbide wheel with proper lubricant at proper speed has been very satisfactory.

Etching—Etching of the material helps considerably in reducing cracking. One company reports

using a 1% hydrochloric acid, 20% nitric acid solution. They etch all parts prior to forming. They etch again after forming. The etch seems to act like burnishing in that it smooths out light scratches. The post-form etching is to achieve an acceptable looking part. This also aids inspection in noting any cracks. Another company reports that their volume of parts precludes etching prior to forming but that they do etch all parts after forming and stress relieving.

Brake Forming—Brake forming of titanium should be done hot, either by heating the part or the tool. One company uses hot brake dies at 1000 F. They do not heat the part, merely allowing it to dwell on the tool and pick up the heat. This is accomplished by using a hydraulic press brake which is slow enough in its action to permit the heat transfer. This dwell time is estimated at 3 to 5 sec. Another company heats the parts in an oven to 1050 F and quickly forms them on a room temperature die in a mechanical press. In this case, the part temperature depends on how fast the operator makes the transfer from the oven.

Serving on the panel which developed the information in the accompanying article were:

Panel leader:

H. C. Emerson, Rohr Aircraft Corp.

Panel co-leader:

J. A. Runner, Santa Monica Division, Douglas Aircraft Co., Inc.

Panel secretary:

J. M. Ohlson, Rohr Aircraft Corp.

Panel Members:

W. T. Kluge, North American Aviation, Inc.

K. A. Wilhelm, Lockheed Aircraft Corp.

Arthur Crom, Convair Division, General Dynamics Corp.

Drop-Hammer Forming—Many titanium parts are formed on the drop hammer. All are formed hot. Some users heat parts in a furnace and form on cold dies. Others heat both part and die. Kirk-site is generally used for dies but its life is much less for hot forming due to the hot parts breaking down the die radii. How often a die is replaced depends to a great extent on part tolerance.

Punch Press Forming—Some forming has been done on punch presses. The parts are heated to 1050 F and formed on cold dies.

Stretch Forming—Much stretch forming of titanium has been done at room temperature. It might be slightly better to form it hot, but the scrap rate for cold forming has been very low. It is important to stretch form titanium at the yield point to get consistent spring-back. One company uses two stretch dies. The first die is an over-stretch and the second operation is a net form. Commercially pure titanium has been stretched down to 0.012-in. gage, but the alloy material has not been stretched below 0.032-in. gage.

It takes five times as long to stretch a part from titanium as it does from aluminum. It has been found that greater elongation and less fracture result from slower stretching.

Hand Forming—Hand forming of titanium is

undesirable. One company prohibits it entirely. Another company allows it either before or after stress relief.

Stress Relieving—All titanium parts (pure or alloy) should be stress relieved after forming. The simple parts that are formed on the hydro press or drop hammer are stress relieved at 1050 F for about 20 min. For more complex parts or those where the contours are critical, the parts are stress relieved in a fixture. Very uniform contours have resulted from this application. The fixtures are made of steel and painted with a heat-resistant paint. The parts are removed from the fixture as soon as the fixture is pulled out of the furnace. This quick removal has no effect on the contour of the parts. One company reports that this process is used also as a "heat restoration" process to return some of the properties lost in stretch forming. This is accomplished by either heating the part in a fixture at 800-900 F for 1 hr and 15 min or 1050 F for 20 min.

(Secretary's report on which this abridgment is based is available in multilith form together with reports of the nine other panel sessions of the 1954 SAE Aircraft Production Forum. This publication, SP-309, is obtainable from the SAE Special Publications Department. Price: \$2 to members, \$4 to nonmembers.)

Turbojet Engines . . .

. . . could be used to power pilotless aircraft. They have significant advantages over ramjets and rockets and should prove less expensive.

Based on paper by **John D. Rogers**, Westinghouse Electric Corp.

RELIABILITY, versatility, and low overall cost are the three basic characteristics of the turbojet engine which recommend it for pilotless aircraft powerplant applications.

The same high degree of reliability which has made turbojets suitable for commercial transport aircraft would be maintained for pilotless aircraft. They may be started on the ground and checked out periodically both for training purposes and to make

certain of power functioning. It may be difficult or impossible to start a ramjet before launching, so that a truly functional pre-flight check or even starting guarantee may be impossible. The control system, which is a large factor in the reliability of the turbojet, may be made relatively simple for pilotless aircraft. And again, the fuels used are easily and safely handled.

Turbojets are suitable for use over a wide spectrum of flight speeds, altitudes, and ranges. It should be possible to make them suitable for operation up to very high Mach numbers.

Thrust at low as well as high flight speeds is one advantage. This is important when the airframe is accelerated to its cruise or maximum flight speed from the launching condition. Comparison between the turbojet and ramjet in this respect is shown in Fig. 1. It is evident that unless the ramjet is to be launched at a very high flight speed, a booster unit such as a rocket or a turbojet would be required.

There is a lack of sound data from which to draw conclusions as to the relative expense of turbojet powered pilotless aircraft and those powered with other means. But there are some excellent reasons why the turbojet can make the least expensive combination, or may be in itself the least expensive powerplant. By combining existing tooling and know-how plus intelligent cost and critical material reduction programs, some of our present and proven

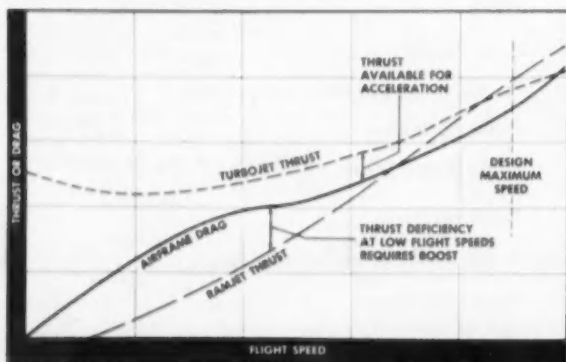


Fig. 1—Comparison between turbojet and ramjet thrust characteristics shows the turbojet to have a marked advantage. It produces thrust at low as well as at high flight speeds. The ramjet requires a booster unit unless launched at a very high flight speed.

turbojet engines can be made into the cheapest possible powerplants for pilotless aircraft.

The development of an advanced turbojet engine is a very large and expensive operation. Therefore, if the development of a piloted and a pilotless aircraft engine is undertaken concurrently, mutual benefit may be derived. With such a parallel program we can draw off the pilotless aircraft engine first in the development program and thus advance the useful state of the art at an earlier date and at

lower cost. The first engine may often be obtained within a relatively short time and the remainder of the program spent in refining it mechanically so that it will pass a 150-hr qualification test.

(Paper "Turbojet Engines for Pilotless Aircraft, Present and Future" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 18, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Turboprop Test Performance . . .

. . . justifies wider military and commercial use. Airframes are now being designed around specific turboprop powerplants.

Based on paper by **Capt. Richard D. Cousins**, U. S. Air Force

THE C-130 Hercules, a turboprop transport, uses approximately two-thirds less runway for take-off than any current piston engine transport having the equivalent gross weight. While no other performance data have been revealed, this is sufficient to indicate the strides being made in turboprop development.

The YC-131C, an off-the-shelf Convair 340 airliner with engine nacelles modified to accommodate YT-56 engines, has completed tests and been put into operation by the Military Air Transport Service. Performance data which are available show the YC-131C's considerable advance over its predecessor, the C-131A.

Take-off distance to clear a 50-ft obstacle is 1680 ft as compared with 2130 ft for the C-131A. At sea level the YC-131C climbs at 2550 fpm as contrasted with 1240 fpm for the C-131A, while at 25,000 ft the rate of climb is 780 fpm as compared to 200 fpm.

Cruising speed is 15 to 30% better, depending on altitude. Landing performance is also superior, ground roll being 1480 ft instead of 1630 ft.

When flown with a design-maximum gross take-off weight of 47,000 lb the aircraft could not maintain 35,000 ft on one engine but could maintain altitude at just over 20,000 ft. Two flights were made at a gross take-off weight of 50,000 lb, 3000 lb over the design maximum, and 35,000-ft altitude was gained with no adverse control characteristics.

Several flights were made to determine the effects of various gross weights and configurations on single engine operation with the "dead" propeller in both feathered and windmilling position. There were no adverse effects other than a slight tail buffet. The full-reverse control capability of the propeller was very good. The most effective propeller braking action was obtained by placing the nose gear on the ground as soon as possible after touchdown, then applying full reverse thrust. If the nose gear was held off to reduce speed before applying reverse pitch, the effectiveness of reverse pitch was reduced appreciably.

The YC-131C exceeded expectations from the maintenance standpoint. Engine accessibility was difficult, but aside from some parts replacement, the engines were found to be quite sound. Combustion liners required frequent replacement. They cracked due to rapid changes in temperature and to hot

spots caused by faulty burner nozzle patterns. Allison engineers designed new liners which have proved far superior.

Hot turbine gases deposited bits of carbon on the bearing seal, causing the seal to stick and allow gases to flow into the bearing. Bits of carbon thus deposited on the bearings caused them to stick. Two bearings were destroyed and a number of rollers developed flat spots. This damage was reduced by cleaning all front turbine bearing units at each inspection.

A major problem was excessive engine vibration during the starting cycle. It appeared that as the engine body and components approached stabilized operating temperatures the vibration decreased. High frequency engine or propeller vibration during operation caused some damage throughout the aircraft. Parts frequently damaged were the starter air ducting, made of very thin-walled stainless steel tubing, and the thin-walled engine oil tanks. A few brackets were also injured.

Crew members reported light and rapid vibration throughout the aircraft on all flights, indicating improper damping. This may be attributed in part to the fact that the YC-131C was not wholly designed for turboprop engines.

Original torque unit piston seals on all propellers gave evidence of disintegrating after about 25 hr of operation. Aeroproducts engineers designed channel-type seals with a stainless steel ring washer as a stiffener. These gave excellent service, and inspection time has been extended to 50 hr. It will be extended still further if the seals remain serviceable.

Several propeller regulators failed. Inspection revealed a wide variation in pressure required to move a distributor valve piston in the governor. The valve required reworking to give the piston more freedom of movement.

Pilots experienced little or no difficulty with operation and control; hence transition from piston or jet aircraft should be no problem. (Paper "USAF Experience to Date with Turboprop Aircraft" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 20, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Softer Blades Stand

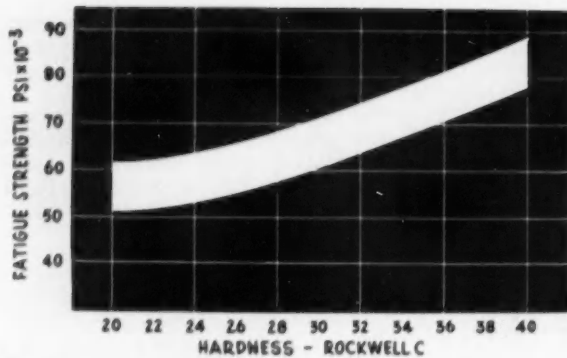


Fig. 1—Fatigue strength increases with hardness.

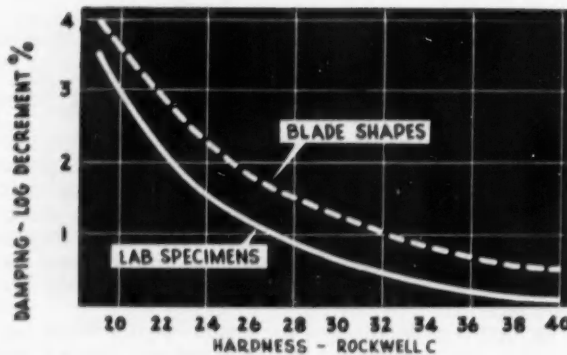


Fig. 2—Damping ability decreases with hardness.

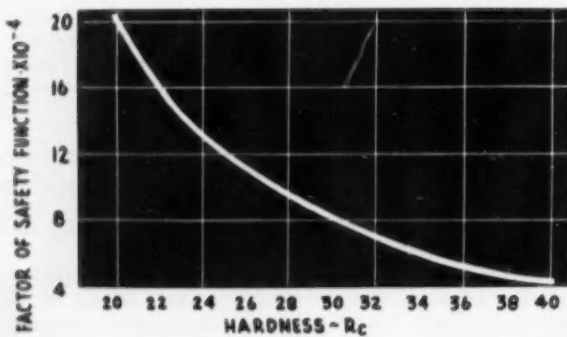


Fig. 3—Safety factor decreases with hardness.

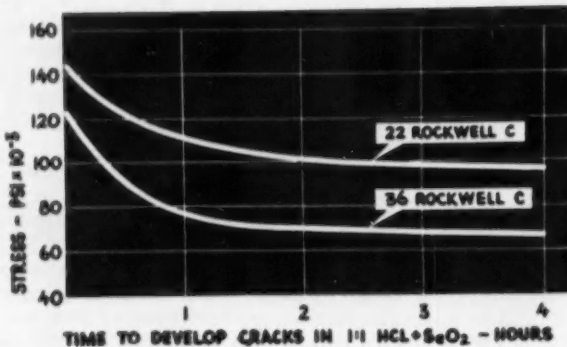


Fig. 4—Softer strips are less susceptible to stress-corrosion cracking.

WHEN J47 compressor blades were failing in fatigue, General Electric found that softer blades—rather than harder, stronger blades—cured the trouble.

The percentage of failed blades was tiny. But even one blade failure in 200,000 affects 1% of the engines produced when each engine contains 2000 blades. So an investigation into the blade failures began.

The investigators knew that fatigue strength increases with hardness. They knew also that damping ability decreases with hardness. As a result of their studies, they found that the optimum combination of fatigue strength and damping for the J47's AISI Type 403 stainless iron blades was in the 20-26 Rockwell C hardness range instead of the 32-38 Rc range which had previously been specified.

Not only did the softer blades show better fatigue life. They were also more resistant to stress corrosion cracking, had better impact strength, and were easier to heat-treat and machine.

AISI Type 403 stainless is essentially iron plus 12% chromium. It had been selected for its good fatigue strength and adequate corrosion resistance. It was known also to have good damping characteristics. But Figs. 1 and 2 show why this combination of attributes didn't come into play in blades hardened to 32-38 Rc: Fatigue strength is high, but damping is low both for actual blades and for the tuning forks used as a check.

Mathematical analysis shows that the safety factor, as far as vibrational stress is concerned, equals the product of fatigue strength and damping. Safety factor versus hardness is plotted in Fig. 3.

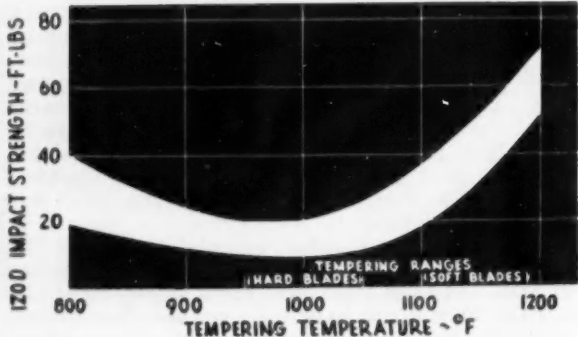


Fig. 5—Impact strength is better for softer blades.

Stress Better in the J47

Just to make sure that they were on the right track with this reasoning, GE investigators checked to see how important material damping is in comparison to (1) damping between blade root and disc and (2) aerodynamic damping.

Testing at GE and NACA demonstrated that in the higher speed ranges for a simple well-fitted dovetail, little or no dovetail damping exists. At high speeds, the centrifugal loading, in a sense, makes the blade dovetail and wheel dovetail act as one, thereby eliminating most of the friction that is otherwise present.

Aerodynamic damping is considerable at high airflows, it was found, but negligible at low airflows. At stall, aerodynamic damping approaches zero.

With these facts, it's easy to visualize a set of operating conditions where material damping is the most predominant type of damping present. At speeds high enough to reduce the effect of dovetail damping, and at flows low enough so that the amount of aerodynamic damping is small, only the internal damping ability of the material itself is left to prevent an excessive degree of blade vibration. Such conditions can and do exist—during acceleration, for example.

Compressor stall of very short duration can occur without the knowledge of the test cell operator or the pilot, as the case may be. Incipient fatigue cracking could start during the period of high vibration. Then blade failure could come about later, perhaps at higher speeds when the centrifugal loading is higher. This, then, would account for the

lack of a consistent pattern as to engine operating conditions at the time of failure.

Before settling on the softer blades, four other factors were checked—and the softer blades showed up as preferable on each score.

1. Resistance to Stress Corrosion—In an accelerated stress corrosion test, strips of material were mechanically deflected to various levels of stress, exposed to a solution of hydrochloric acid and selenium dioxide and the time for cracking to take place recorded.

Fig. 4 compares the results on strips heat-treated to the high hardness range and strips treated to the low hardness range. In the case of the soft blades, either a significantly higher stress can be withstood before cracking occurs, or a greater time is required to produce cracking at the same stress level. These curves flatten out with time and tend to be well above the fatigue strength for the soft blades but below for the hard blades. Furthermore, the stress relief temperature can be higher for the soft blades than for the hard blades without lowering the hardness of tempering. This reduces more of the internal residual stresses, which play a major role in the stress corrosion mechanism.

2. Impact Strength—The higher tempering temperature applied to make the blades softer correlates with better impact strength, as Fig. 5 shows. (These tests were made at room temperature, but values would be the same for the 400–450 F maximum compressor operating temperatures.)

Since foreign-object damage had accounted for 30% of all engine removals at other-than-scheduled-overall times, serviceability with the softer, more impact-resistant blades ought to be much improved.

3. Heat Treatment—For optimum physical properties, compressor blades should be given a full (quench and temper) heat-treatment after forging. Fig. 6 shows what the heat-treater is up against, when trying to temper 403 stainless to 32–38 Rc. The normal heat-to-heat variation alone will cause many blades to fall outside the specification hardness range. Such blades, of course, have to be given a time-consuming reheat treatment. Contrast this with the relatively simple problem of hitting the correct hardness range with the practically flat tempering curve in the hardness range of 20–26 Rc. No

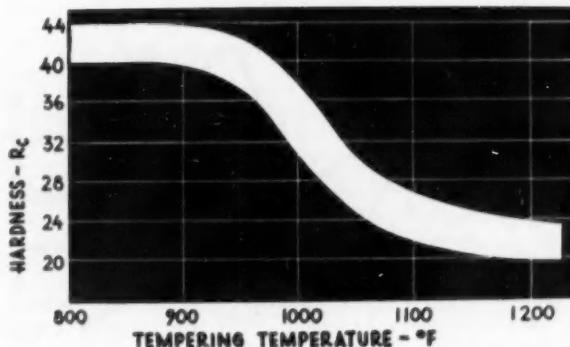


Fig. 6—Tempering temperature does not have to be so closely controlled to temper blades to 20–26 Rc as it does to temper them to 32–38 Rc.

wonder the heat-treating department prefers to see soft blades in use.

4. **Machining**—Although it does not necessarily follow that the softer the material, the better the machinability, 26 Rc Type 403 material is easier to cut than 38 Rc. Certain adjustments in the various machining processes had to be made initially. But with experience, the soft blades proved to be easier to handle in the machine shop than did the hard blades.

An actual cost comparison between the hard and soft blades is not too easy to make. Soft blades were

introduced at the time of increasing production rates. In addition, cost reductions because of improved manufacturing techniques were constantly being put into effect. A conservative estimate, however, indicates that at least \$50 per engine is saved with the use of soft blades. With production figures in the thousands, even this small saving can rapidly become very impressive.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

New Brake Test . . .

. . . employs an oscillograph instead of stroboscope method to check drum distortion, and proves great saver of time and labor.

THE recently developed oscillograph method for testing brake drum distortion requires one man and is accomplished in 0.4 sec. This is in sharp contrast to the customary stroboscope method which takes two men and about 8 hrs.

In the oscillograph method, a reed with strain gages on both sides is mounted as shown in Fig. 1. The balancing circuit is built into the bracket which carries the reed. The output of the strain gages is fed to the oscillograph through slip rings. Four of these devices can be mounted on the dynamometer so that the distortion of all four locations—drum

ring, radially, (1) at its open end, (2) middle, and (3) back end; and the drum back, laterally, (4) near its outer periphery—can be taken at one time. With the stroboscope method, each of these locations is tested separately.

When the test is run, the dynamometer is brought up to speed, a brake application is made at the proper torque, and the drum deflections at all four points across the drum, and for every angular increment, and for several revolutions are traced.

A typical distortion pattern at one point on the drum is shown in Fig. 2. The torque is also plotted. The diagonal line serves the purpose of orienting the angular location of the deflection.

Although this test has been carried out with a dynamometer, we see no reason why it could not have been done right on the vehicle, and on all four wheels simultaneously if desired. (Paper "Improved Techniques Used in Evaluating Brake Performance" was presented at SAE Golden Anniversary Passenger Car, Body, and Materials Meeting, Detroit, March 3, 1955. It is available in full in multilith form together with three other papers on brakes as SP-138 from SAE Special Publications Department. Price: \$1.25 to members, \$2.50 to nonmembers.)

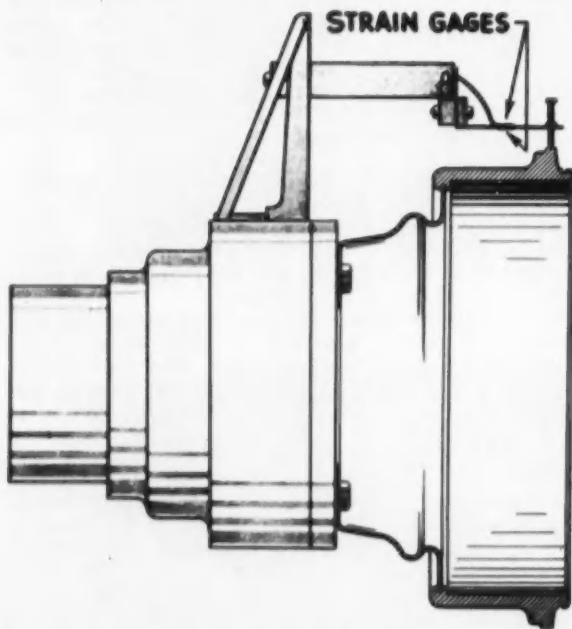


Fig. 1—Device used for oscillograph testing of brake drum distortion consists of a reed with strain gages on both sides, mounted as shown. The balancing circuit is built into the bracket carrying the reed. Four of these are mounted on the dynamometer.

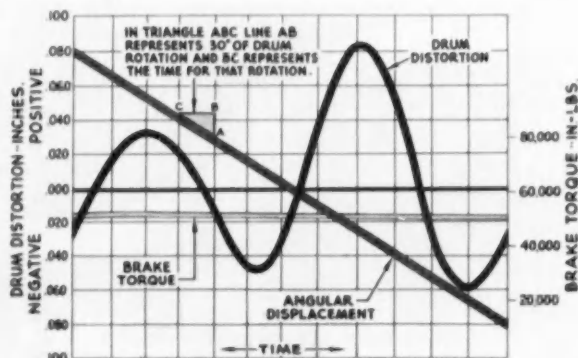


Fig. 2—This is a typical distortion pattern at one point on a brake drum. Torque and angular displacement are also plotted.

Pick Your Men . . .

. . . before training for first level supervisors. Not all engineers want to supervise or have the makings for it. The potential must be uncovered and there are ways to do it.

Based on panel secretary's report by **Jules F. Honesco**, North American Aviation, Inc.

TRAINING of first level supervisors begins with a decision on training needs and this is a management responsibility. There are four approaches to a decision:

- Establish an activity analysis program to get at the basic responsibilities of the individual and use this as the core of training needs.
- Ask management men what they think are the needs in the technical, communications, and human relations area.
- Ask employees how they feel about the way they are supervised. This approach will indicate the general areas in which training is needed.
- Establish education committees to determine needs. This is used in establishing programs both within and outside the plant.

Although training and development go hand in hand, there is a difference between them which should be kept in mind. Training is a short-term measure designed to teach a skill, knack, or procedure; development deals with potentials involving feeling and intuition and can be self-taught. The trainer's job is to motivate the trainee to self-improvement.

There are two factors to be considered in training. One is work habits, the other is interest. Work habits can be changed by training, but the trainer must be good to be able to make a man wish to improve his work habits. Interest is more difficult to handle. An engineer may have no interest in becoming a supervisor. Therefore, selection for supervisory potential is quite essential.

The real job is to identify and develop this interest. There are six ways to do it:

1. Encourage engineers to engage in voluntary programs.
2. Appraise the individual in terms of activities for which he is responsible.
3. Provide opportunities for participation or leadership in community or company group activities.
4. Give committee assignments for discussion of specific company problems.
5. Delegate responsibility wherever interest is displayed.
6. Provide synthetic experiences such as group discussions of problems of department inter-relationships.

The boss, variously defined as the leadman, assistant foreman, foreman, or project engineer, is the best man to do the training. He knows where the need exists and is in the best position to follow through. The function of the training department should be to act as an assistant to the boss.

There are many training methods in use today. About 50% of the time the conference method is used. The conference is a planned informal meeting where ideas are exchanged on related interests. The advantages of this method are that it uses normal thought processes, involves all four steps of preparation, presentation, application, and follow-up, is active, and everybody trains. On the other hand it can turn into a conversational boat ride unless well led, it consumes and sometimes wastes time, and participants must be limited to about 15.

The case study method requires a study, usually written, of a specific case. It is an effective substitute for experience. It brings out a variety of solutions and makes possible reaching a conclusion. The method can be used for groups as large as 100. There are disadvantages in that men are reluctant to expose their ideas to criticism and are often more prone to enlarge on the facts than reach a solution.

A third method is role playing. It is active and the participants learn by doing. Since the possibility of misunderstandings is great, one learns to be more sensitive to what others say and to the feelings lying behind their words. The players must be carefully briefed lest they forget the subject and end by merely play-acting.

The planned experience method, which is really on-the-job training, has the merit of being simple and easy to use. The trainee sees the goal clearly and gets a sense of accomplishment as his ability increases. The trainer is able to evaluate performance on a very positive basis. Like other methods, this one has drawbacks. The areas of training depend largely on the trainer's subjective evaluation of the trainee's needs, also, what may be transferred is bias. Unless good records are kept for higher management, the program is likely to be unorganized and ineffective.

(The full Secretary's report of which this article is an abridgment is available as SP-309 along with reports of the nine other panels held at the SAE National Aeronautic Meeting in Los Angeles on October 6, 1954. Price: \$2.00 to members, \$4.00 to nonmembers. Chairman of this Panel on Education in Industry was John A. Peart, North American Aviation, Inc. Members were M. S. Lachman, Convair Division, General Dynamics Corp., E. A. Puffer, Douglas Aircraft Co., J. J. Schwarz, Lockheed Aircraft Corp., and Elmer F. Sproule, Hughes Aircraft Co.)

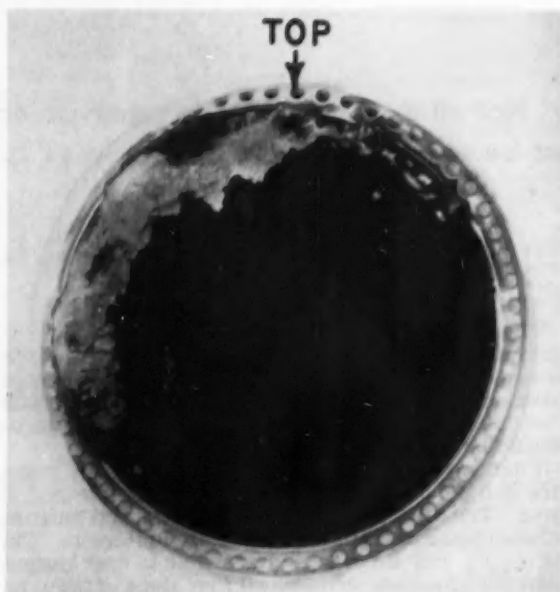


Fig. 1—Combustor A liner deposits—20-hr cruise operation at 30,000-ft altitude, JP-3 fuel

Jet Engines

STUDIES of deposit formation in jet engines indicate that:

1. No single number can describe completely the severity of deposits.

2. Location and magnitude of deposits depend on combustor design.

3. Combustors can be designed so that they are tolerant of wide ranges of fuel volatility and composition.

4. Deposit weight is a fairly good indication of fuel cleanliness, if deposits from several fuels used in the same engine are compared.

5. Light deposits may cause more trouble than heavy ones, if the former are formed at critical spots.

6. Deposit predictions based on fuel properties or simple burning tests are not always reliable because fuels do not behave the same in different combustors.

7. At first, deposits build up in direct proportion to running time. Later, the buildup rate begins to fall off until, finally, the deposit level becomes constant.

8. The early rate is a better indication of fuel cleanliness than is the equilibrium deposit level.

9. Deposits generally increase with decreasing fuel volatility (heavier fuels) and increasing degree of fuel unsaturation (more aromatics and olefins).

These conclusions are based on a study of jet-engine deposits that was instituted because the

problem has now become serious. Previously, when straight-run fuels were used almost exclusively, carbon deposits caused little trouble. Today, two circumstances have combined to change this picture. They are:

- Widespread use of JP-3 and JP-4 fuels (MIL-F-5624A).

- Introduction of many different engine models.

Test Fuels

The tests on which these conclusions are based were conducted with the fuels and blends described in Table 1.

Combustor operating conditions were selected to simulate cruise conditions at the lowest altitude (maximum pressure) permitted by the test facilities. Depending on the pressure and mass-flow requirements of the particular combustor under test, the altitude level simulated during the deposit test program varied from 20,000 to 30,000 ft. Although there is some evidence that deposits increase with combustor operating pressure, these conditions seem to be more nearly representative of the conditions prevailing during a typical jet flight. The duration of the deposit runs, except as noted otherwise, was three hours. This test duration was selected after studies showed that longer running time, while producing more deposits, resulted in poorer test reproducibility.

Test Data

Figs. 1 and 2 show combustor parts from two different engines following 20-hr runs on the same JP-3 fuel. Fig. 1 is a view looking into the liner of

Have Deposit Problems, Too!

C. M. Kuhbach, W. F. Ritcheske, and
K. H. Strauss, Texas Co.

Based on paper, "Fuel Properties and Jet-Engine Combustor Performance," presented at the SAE National Aeronautic Meeting, Los Angeles, Oct. 7, 1954.

combustor A. There is a heavy buildup of deposits in the midsection of the liner. The spark plug, fuel nozzle, and other portions of this combustor were almost free from deposits. The total deposit weight was about 100 g. There was no loss in combustion efficiency from these large deposit formations. There were indications, however, that the deposits were disturbing the cooling airflow over the liner and that, with continued running time, the liner would have overheated and failed.

Under similar operating conditions, the liner of combustor B was almost free from deposits but the fuel nozzle and spark plug had the appearance shown in Fig. 2. Although the deposit weight in combustor A was many times greater than that in combustor B, the latter had a decidedly detrimental effect on performance. The combustor could not be restarted in the condition shown.

Fig. 3 shows the type of deposit formations ob-



Fig. 2—Combustor B deposits—20-hr cruise operation at 30,000-ft altitude, JP-3 fuel



Fig. 3—Vaporizing tube deposits—6-hr cruise operation at 20,000-ft altitude, No. 2 fuel oil

Table 1—Inspection Tests of Fuels

	Aviation Gas 80	Jet Fuel JP-3	Jet Fuel JP-4	Jet Fuel JP-1	Diesel Fuel	No. 1 Fuel Oil	No. 2 Fuel Oil	No. 4 Fuel Oil	Blend No. 1 ^a	Blend No. 2 ^b	Blend No. 3 ^c	Blend No. 4 ^d	Blend No. 5 ^e	Blend No. 6 ^f
Gravity, deg API	68.0	57.3	54.4	40.7	37.2	41.0	31.6	13.2	56.5	52.7	50.5	47.3	46.9	45.3
ASTM Distillation, F														
IBP	113	117	139	316	418	360	392	370	129	139	133	142	125	104
10% Evaporated	160	173	190	339	458	408	454	486	216	225	225	229	194	175
20% Evaporated	179	198	212	348	—	—	481	522	265	255	260	263	239	263
50% Evaporated	212	245	293	380	519	459	530	618	393	354	361	382	355	353
90% Evaporated	244	435	421	466	580	538	619	722	483	479	475	467	484	481
EP	316	480	478	512	617	582	702	—	543	541	539	535	537	525
RVP, psi	5.3	5.2	2.4	0	0	0	0	0	2.5	2.2	2.1	2.2	5.0	6.2
Aromatics, %	4.5	13.5	10	18	19	10	28.5	80	3	19	27	26	16	22
Olefins, %	0	0	—	1.0	2.5	3.0	6.0	20.2	0.9	1.7	1.7	4.8	2.0	10.1
Sulfur, %	0.019	0.023	0.028	0.053	0.250	0.160	0.240	1.310	0.003	0.021	0.018	0.013	0.070	0.410
Carbon/Hydrogen Ratio	5.56	6.12	5.90	6.35	6.41	6.42	6.62	9.00	5.50	5.92	6.09	6.42	6.39	6.49
Net Heating Value, Btu per lb	18,970	18,650	18,770	18,610	18,420	18,680	18,200	17,270	19,050	18,890	18,770	18,570	18,680	18,540
Smoke Point, mm	45	30	30	19	20	23	12	Un- suita- ble	42	26	22	18	19	14
Smoke Volatility Index	87	66	66	45	20	26	13	Un- suita- ble	65	52	51	42	44	41
Freezing Point, F	Below -76	Below -76	Below -76	Below -76	0 ^g	-35 ^h	+5 ⁱ	-10 ^j	Below -76	Below -76	Below -76	Below -76	Below -76	Below -76
Volumetric Average Boiling Point, F	208	275	299	391	519	466	533	611	371	353	363	365	347	341
Volume % Boiling under 400 F	100	86	86	62	0	7	2	—	54	63	69	57	61	63

^a Low-deposit JP-4 base fuel prepared from blend of isoparaffins.

^b Fuel blend No. 1 with 15% benzene nucleus aromatics boiling at 230-306 F substituted for isoparaffins of same boiling range.

^c Fuel blend No. 2 with 10% benzene nucleus aromatics substituted for isoparaffins of same boiling range. Aromatics had ASTM distillation of 350-570 F, with 50% point of about 370 F.

^d Blend No. 2 with 10% naphthalene nucleus aromatics boiling at 465-480 F substituted for isoparaffins of same boiling range.

^e JP-3 type of fuel.

^f Referee JP-3 type of fuel.

^g Pour point, F.

Table 2—Relative Deposit Ratings^a

	Combustor D	Combustor E
JP-4 Fuel	0.2	0.4
JP-1 Fuel	1.0	1.0
No. 1 Fuel Oil	2.1	—
Diesel Fuel	1.7	4.4
No. 2 Fuel Oil	2.6	10.2
Blend No. 1	0.5	0.5
Blend No. 2	0.2	1.5
Blend No. 3	0.2	2.3
Blend No. 4	1.7	6.3
Blend No. 5	1.0	0.3
Blend No. 6	—	5.1

^a JP-1 equals 1.0.

Table 3—Deposit Weights of Special Blends

Combustor E Test Duration: 3 hr			
	Total	Aromatics, % over 400 F	Deposit Weight, g
Blend No. 1	3	2	0.36
Blend No. 2	19	2	1.11
Blend No. 3	27	4	1.71
Blend No. 4	26	9	4.65
Blend No. 5	16	11	2.40
Blend No. 6	22	19	3.66

served in a vaporizing combustor. This is a photograph of a vaporizing tube assembly following a 6-hr run on fuel oil No. 2. This quantity of deposit resulted in no loss of performance nor was there any damage to combustor parts.

These illustrations show that deposits vary considerably in their character and location. Combustor A ran with a relatively clean fuel nozzle and plug but a heavy, localized liner deposit. Combustor B ran with a relatively clean liner but a fouled plug and dirty fuel nozzle. It is reasonable to assume, therefore, that a combustor can be designed to operate under the same conditions imposed on combustors A and B, but without any localized deposit buildup. Considerable progress is being made in this direction by the engine builders.

Some typical deposit test results are given in Table 2 for 11 fuels on two combustors, one an atomizing combustor and the other a vaporizing combustor. So the results from these combustors can be compared with each other, the data are presented on a relative basis.

Inspection of these deposit test results shows that combustor D is much less sensitive to fuel composition than is combustor E. For example, combustor D rated fuel oil No. 2 only 2.6 times as dirty as JP-1, whereas this factor was 10.2 in combustor E.

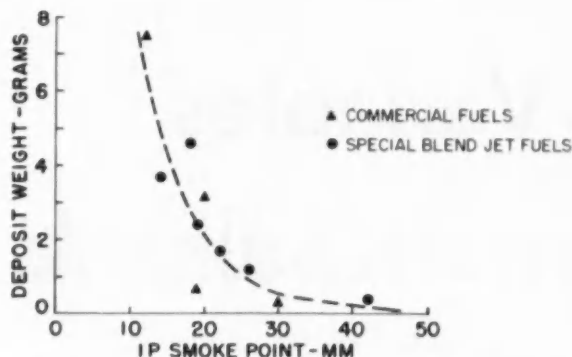


Fig. 4—Smoke point versus deposits for combustor E—3-hr run

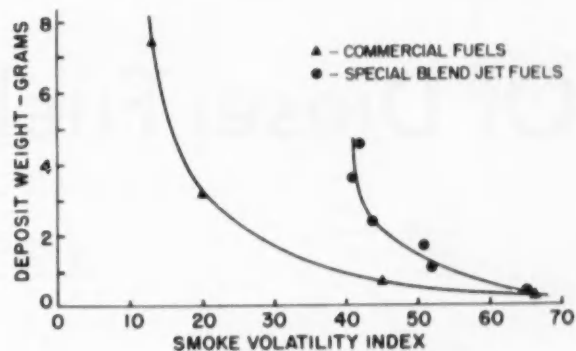


Fig. 5—Smoke volatility index versus deposits for combustor E—3-hr run

Neither did these two combustors rate the fuels in the same order. These results show that it will be difficult to develop a single small-scale burning test or rating device suitable for wide ranges of fuels and engines.

Actual deposit weights obtained in combustor E on the six special blend fuels that were described earlier are given in Table 3. This table also contains the experimentally determined total aromatic content of the fuel fraction boiling above 400 F. The latter has been suggested as a much better indication of burning quality of a fuel than the total aromatic content. Although there is a rough correlation between the aromatic content of the fuel and deposits, it can be seen that neither the total aromatic content nor the percentage of aromatics boiling above 400 F gives an accurate prediction of deposit formation in this combustor.

A review of all the deposit results on combustor E (see Table 2) shows that blend No. 1 was about equal to the commercial JP-4 fuel in deposits. The addition of various aromatics to blend No. 1 kept increasing deposits until blend No. 4 (containing just slightly more aromatics than are permitted by the JP-4 specifications) resulted in more deposits than were obtained with diesel fuel. None of the special blends however, showed deposits as heavy as fuel oil No. 2.

Within the past few years there has been considerable interest in the development of an inspection test or burning test from which the deposit-forming characteristics of a fuel could be estimated. Within the past year, one such test or factor known as the smoke volatility index (SVI) has been adopted as a requirement of the jet fuel specification MIL-F-5624B. This factor is made up of: (1) the smoke point and (2) the volume per cent of the fuel boiling under 400 F.¹

Prior to the adoption of the SVI, the IP smoke point² was considered to be a fairly good indication

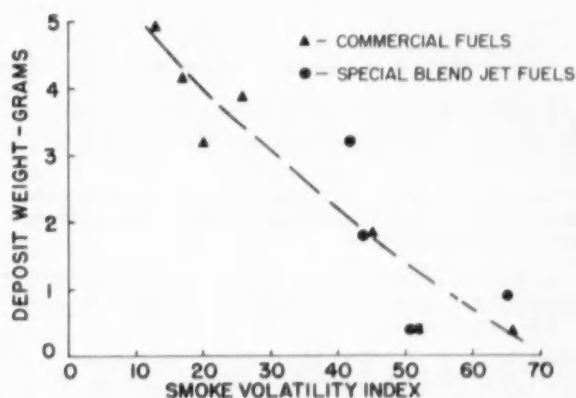


Fig. 6—Smoke volatility index versus deposits for combustor D—3-hr run

of deposits. Fig. 4 shows a plot of IP smoke point versus combustor E deposit weights. While there is a general correlation, it is apparent that for only a relatively small variation in smoke point in the 14–24-mm range, considerable differences in deposit formation occur. Obviously, this smoke point deposit correlation leaves something to be desired.

If the SVI is employed, a picture such as is shown in Fig. 5 is obtained. The commercial fuels line up along one curve and the special blends arrange themselves on a second curve. Because of the volatility term in the SVI factor, the SVI discriminates heavily between light and heavy fuels that happen to produce the same deposit.

Fig. 6 shows a plot of deposit weight versus SVI for the same fuels run in combustor D. These results differ considerably from those obtained in combustor E. Although the relationship between SVI and deposits is not well defined, there appears to be no differentiation between the two different series of fuels. Discrimination between fuels in the range of chief interest (SVI from 45 to 55) is not entirely satisfactory.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

¹ SVI = smoke point + 0.42 volume per cent boiling under 400 F.

² IP smoke point refers to a method of evaluating smoking tendencies developed for kerosene by the British Institute of Petroleum.

Of Diesel Fuel Variables

Sulfur Is

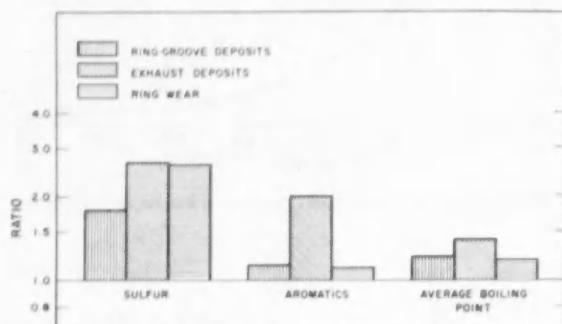


Fig. 1—Average effects of fuel composition

COMPREHENSIVE investigations of the effect of fuel composition on six automotive diesel engines reveal that:

1. Sulfur tends to increase deposits and wear throughout these engines over a wide range of operating conditions.

2. Higher aromatics contents and average boiling points increase deposits at specific points in the engines, but have little effect on wear.

3. The magnitude of these effects differs so much with engine design and type of operation that generalizations are unwise.

Average Effects

Fig. 1 shows the average effects of sulfur, aromatics, and average boiling point on deposits and wear for all engines and conditions. (Results are presented as ratios of deposits or wear with fuels of high sulfur content, aromatics content, or average

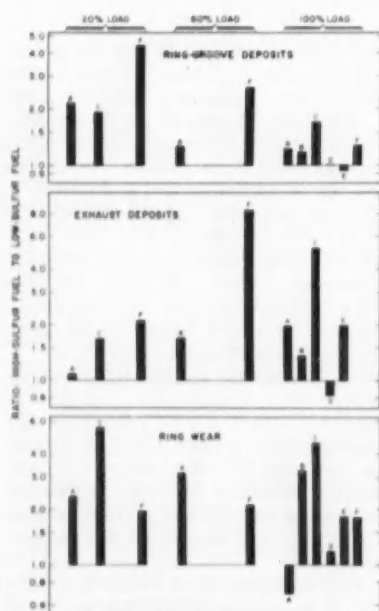


Fig. 2—Effect of sulfur

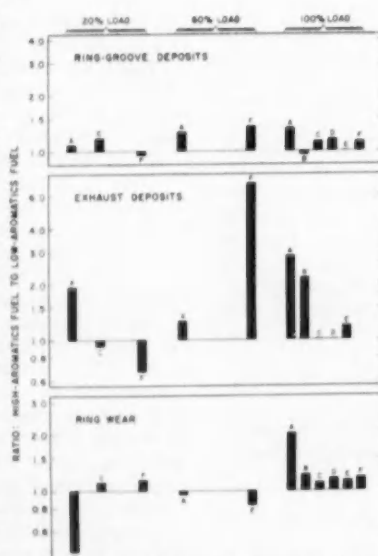


Fig. 3—Effect of aromatics

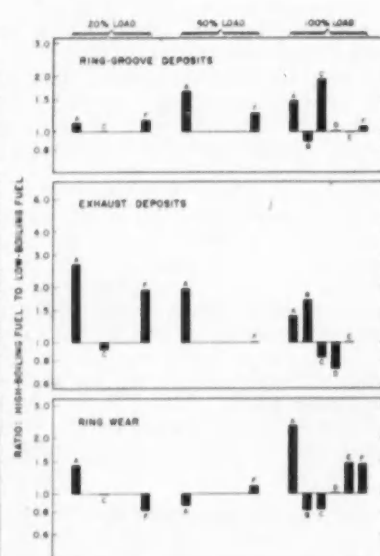


Fig. 4—Effect of average boiling point

Worst Offender

Lamont Eltinge, D. S. Gray, and
H. R. Taliaferro, Standard Oil Co. (Ind.)

Excerpts from paper "How Fuel Composition Affects Diesel Deposits and Wear," presented at SAE National Fuels & Lubricants Meeting, Tulsa, Nov. 4, 1954.

boiling point to deposits or wear with fuels of low sulfur content, aromatics content, or average boiling point. Increases are shown by ratios greater than 1; decreases by ratios less than 1. A separate bar is shown for each engine and operating condition; letters above the bars identify the engines. Presentation of data in terms of ratios emphasizes reactions to fuel variables and deemphasizes effects of engine design.)

Increasing sulfur content from 0.25% to 1.25% increased deposits and wear 135%. Increasing aromatics content from 14% to 45% increased exhaust deposits 101%. Increasing average boiling point 200 deg increased exhaust deposits 41%. Exhaust deposits appear much more sensitive to fuel quality than ring-groove deposits. Wear is more sensitive to sulfur content than to aromatics content or average boiling point.

Effects in Individual Engines

The effects of sulfur content, aromatics content, and average boiling point in the individual engines tested are illustrated in Figs. 2-4.

Sulfur Content—The effects of increasing sulfur content from 0.25% to 1.25% are shown in Fig. 2. Each bar represents the average effect of increasing sulfur in fuels containing 14% and 45% aromatics.

Ring-groove deposits increased when sulfur was increased. The effect varied in magnitude between engines and decreased as load increased. At 100% load, 1% more sulfur increased deposits an average of 20%. However, engine C showed a 70% increase, engine D showed no effect, and engine E showed a slight decrease. At 20% load, the effect was much greater; ratios ranged from two to four.

Exhaust deposits also increased with sulfur. The ratios depended on engine design and increased with load. Although most sensitive to increased sulfur, exhaust deposits at 100% load actually were too small in magnitude to be significant. In engine F, they were even too small to determine accurately.

Ring wear usually doubled when sulfur was in-

creased. Engine C was even more sensitive: wear quintupled. Engine A reacted to sulfur in an entirely different way at 100% load. The unexpected 30% decrease in wear was verified by several check tests. Wear at 100% load in this engine appeared more sensitive to sulfur type than to total sulfur content; the addition of 0.2% of an active sulfur compound to fuel U gave wear identical to fuel V. This phenomenon may be related to borderline lubrication in this particular combination of engine design and operation.

Aromatics Content—The effects of increasing aromatics content from 14% to 45% are shown in Fig. 3. Each bar represents the average effect of increasing aromatics in fuels of high and low sulfur content.

Ring-groove deposits increased only slightly with increased aromatics content.

Exhaust deposits did not react to aromatics in a uniform fashion. The effect was minor in engines C, D, and E. At 20% load, where deposits are greatest and the change is most significant, deposits doubled in engine A but decreased 30% in engine F. At 60% load, the ratio was 1.3 in engine A and 7.1 in engine F. At 100% load, deposits tripled in engine A and doubled in engine B.

Ring wear was almost unaffected by aromatics. At 20% load, wear was slight; even the difference shown for engine A could be charged to experimental error. At 100% load, the increase in wear in engine A was verified; it appeared related to the combination of engine design and the low ignition quality of aromatic fuels. Wear was much lower when an ignition accelerator was added to fuels W and X.

Average Boiling Point—The effects of a 200-deg increase in average boiling point are shown in Fig. 4.

Ring-groove deposits increased with average boiling point in engines A and C, but were unaffected in engines B, D, E, and F. Ratios were greatest in engine A at 60% load and increased with load in engine C.

Exhaust deposits were small at 100% load, and average boiling point had little effect on them. At

20% load, where exhaust deposits were heavy, the increase in average boiling point doubled or tripled deposits in engines A and F.

Ring wear was little affected by the increase in average boiling point. The low sulfur and aromatics contents used gave wear so low that even the in-

crease shown for engine A at 100% load was insignificant.

(Paper on which this abridgment is based is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Excerpts from Discussion

Consider the Whole System

—L. A. Blanc

Caterpillar Tractor Co.

THE form in which the data are presented does not allow an easy assessment of the results in terms of effect on engine life.

The method of reporting also has its dangerous aspects. For example, what information we have on the subject indicates that oil control is probably the single most important variable in the formation of exhaust deposits. I wonder if the normal variation in oil consumption could have affected the results as they are reported.

A second point—the quality of the lubricating oil and the relationship of the drain period to the fuel and operating conditions of the engine—will have a considerable effect on ring-belt deposits. Relationships valid for one combination of conditions may be quite different for another.

I should like, therefore, to plead for the examination of such problems to be made on the consideration that in each case we are dealing with a whole system. This system includes the physical and chemical conditions which result from the design and materials of the engine, its combustion system, its operating conditions, and the composition of the fuels and lubricants involved.

Corroborating Data

—H. C. Hunter

Gulf Oil Corp.

ENGINE test results from a series of runs made in the GM 3-71 engine mainly under low-speed, light-load conditions bear out the authors' findings on the relationship between rate of formation of engine deposits and the properties of the fuel.

Table A shows the comparative deposit-forming tendencies of two distillate fuels (A and B) representative of the types of fuels widely used in the United States at the present time in automotive-type diesel engines. The most important difference between these fuels is the sulfur content; fuel B having 13 times as much total sulfur as fuel A. The difference in chemical composition is shown by the higher aromatics and olefin content of fuel B; and this is reflected in the cetane number. The ignition quality of B is not low by present standards; modern diesel fuel specifications usually allow 45 cetane numbers as a minimum limit. The two fuels are in the same volatility range. In the low-speed, low-load test, fuel B, with the higher sulfur and aromatics content, gave almost twice as much deposit on the exhaust valves as fuel A.

These results can also be compared with the results of similar tests run with two fuels, (C and D),

Table A—Diesel Fuel Performance Comparison

Fuel Identification	Representative of Current Distillate Fuels		Fuels Containing 50% Cracked Distillate Stock		100% Cat-Cracked Fuels		Blend of Straight-Run and Cat-Cracked Fuels
	A	B	C	D	E	F	G
Make-up (by Vol.), %							
Straight Run	100	80	50	50	0	0	72
Thermofofor Catalytic Cracked	0	0	50	0	100	0	0
Fluid Catalytic Cracked	0	20	0	50	0	100	28
Properties							
Cetane Number	56	48	49	35	43	19	46
Sulfur Content, %	0.05	0.64	0.21	1.15	0.19	0.97	0.80
Aromatics (by Vol.), %	12	18	16	28	23	42	22
Olefins (by Vol.), %	2.5	11.4	8.3	22.1	13.6	25.8	14.4
Distillation (End Point), F	628	639	634	630	656	618	641
Heat Content (Gross Calculated), Btu/lb	19,710	19,590	19,570	19,390	19,400	19,050	19,550
Engine Test Results							
Exhaust-Valve Deposits (Average), G	0.36	0.65	0.51	1.08	1.40	1.69	0.35
Fuel Consumption, lb/bhp-hr	0.50	0.53	0.52	0.54	0.55	0.58	0.45
Engine Conditions							
Duration of Test, hr	100	100	100	100	100	100	500
Speed, rpm	1200	1200	1200	1200	1200	1200	1700
Load, Bmep, psi	35	35	35	35	35	35	74

both of which contain 50% cracked distillate stock and hence contain appreciable amounts of aromatic hydrocarbons. The volatility factor is the same in each; but the use of fuel D, which had a little over five times as much sulfur as fuel C, resulted in just about twice the weight of valve deposit.

Next, the results with all straight-run fuel can be compared with those for 100% cat-cracked fuels (E and F). Here the effects of individual variables are not clearcut, since we have variations in sulfur content, hydrocarbon composition, and volatility as well. However, note that cracked fuel F, with five times the sulfur content of cracked fuel E, gave 169 cg of valve deposit against 140 cg for fuel E, in spite of its higher volatility. Fuel F actually would be classified as a No. 1 distillate because of its 618 F end point.

As the authors have shown, engine operating conditions have a greater influence than fuel properties on deposit formation. Table A also illustrates this. Compare fuels A and B with G, another blend of straight-run and cat-cracked distillates which was run in the engine at a higher speed and load than was used in the previous runs. Although fuel G was higher in sulfur and cracked content than fuel B, it gave no more valve deposits under high-output conditions, in spite of the longer time of operation, than the low-sulfur straight-run fuel A operating at the low-speed, low-load conditions—which means at lower combustion-chamber temperature. Note that the volatility of these three fuels is not significantly different, all being in the low range of the No. 2 fuel boiling-point bracket. The ignition quality of these three fuels also is of no importance, since they are all well above the cetane-number level at which any commercial diesel engine that we know of would recognize the difference.

To sum up, we would say that, within the limits of light to medium boiling-range No. 2 diesel fuels, aromatics content has a significant but minor effect on deposit formation in the exhaust system and that boiling range has even less effect; but that sulfur is the bad actor. This is in complete agreement with the authors' Fig. 1.

Let's Consider Sulfur Type

—C. H. Lancaster
International Harvester Co.

WE believe the sulfur effects on wear should be studied from the standpoint of the degree of activity of the sulfur and its attachment pattern to the hydrocarbon component of the fuel mixture. Work in this direction might explain the differences that we have noted in some of our work in full-scale engine cooperative studies. Also, in this connection, we have not yet been able to explain certain anomalies that are evident in our work on deposits and wear. Sulfur by itself does not explain dissimilar deposits and wear effects. We believe that very careful selection of diesel fuels must be made in work of this kind in order to evaluate the hydrocarbon effects. Our present efforts are along these lines preparatory to initiating a series of engine tests to establish the relationships.

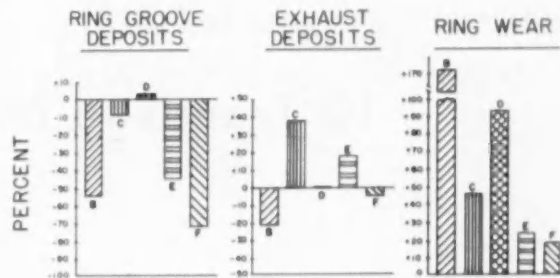


Fig. A—Effect of fuel composition—base line, fuel A

When 6 "Similar" Fuels Aren't

—B. L. Figlewski
Sinclair Refining Co.

IN the past few years, thinking has had to be revised somewhat as to what constitute suitable fuels for different types of engines and different operating conditions. There are no clearcut criteria that can be used for predicting fuel performance under a variety of conditions, except by testing in actual engines.

This thought can be illustrated by the results of a series of tests with six diesel fuels closely similar in the usual characteristics. The sulfur content varied from 0.13% to 0.25%, the aromatics content from 16.8% to 22.3%, and the average boiling point from 497 F to 528 F. The spreads in the other inspection tests between the six fuels were of the same magnitude.

These fuels were run on the dynamometer in a 2-cyl, 2-stroke, open-combustion-chamber diesel engine under the same test conditions and with the identical lube oil.

Fig. A shows that wear and deposit performance was quite different for these six fuels so similar as far as laboratory inspection data were concerned. Fuel A was used to obtain the base run with which the other fuels were compared since this fuel was a straight-run, low-sulfur, clean-running product on which laboratory and service performance data were available. The comparisons are shown as percentages better or worse than the base fuel.

These data show that ring-groove deposits ranged from 72% less deposit with fuel F to 4% more deposit with fuel D than that obtained with the base fuel A.

The differences in amounts of exhaust-port deposits were less than the differences in ring-groove deposits. Fuel B produced 22% less exhaust-port deposits while fuel C produced 39% more deposits than fuel A.

Ring wear with the five fuels was greater than that obtained with fuel A; 172% more with B down to 19% more with fuel F.

It is apparent that the six fuels tested were not the same on a performance basis although from their physical tests it might be assumed that they would all run about the same in an engine.

10 Trends to More Effective

Quality

RAPID technological advancements are continually making new and greater demands upon quality control. This has caused management to re-evaluate its

quality control policies and adapt new methods and techniques of inspection, testing, training, and auditing. Here's what's happening in the field:

1. New Methods and Techniques of Inspection are Being Adapted

Since products are becoming more complex and costly, detecting errors at the earliest possible point is becoming increasingly important. Ultrasonics, fluoroscopy, X-ray, dye penetrants, fluorescent penetrants, and magnetism are being used more and more for inspection. With these nondestructive test methods a higher degree of quality assurance is possible, since 100% inspection can be made on

critical parts. Destructive testing is also being increased in both scope and accuracy.

On the production line, inspection is requiring tighter tolerances. Test instruments usually found only in the precision laboratory—such as optical comparators, toolmaker's microscopes, pneumatic gages, and electrolimit gages—are now being used in the shop, supplementing "go-no-go" gages.

2. Efficiency of Inspection Labor is Being Improved

The quality control inspector is being given better training, modern visual aids, efficient work patterns, and more effective supervision to help him do his job better.

Visual inspection aids—which list all inspection requirements with a photograph or drawing of the part—tell the inspector what the finished job should look like, what assemblies it should contain, the location of critical points, and what should be inspected carefully.

Inspection items are being classified according to their importance, so that the inspector knows in what areas to spend more time. One quality classification system takes into account where in the manufacturing process an error is found, or whether it slips by until final inspection.

To learn the latest control techniques and concepts, quality control specialists are being encouraged to communicate with other companies and

with technical societies.

On-the-job training programs are increasing. The practice of sending employees to schools for technical training is upgrading the skill level of both inspection and production workers.

At the same time, jobs requiring highly diversified skills are being simplified to essential operations with simple tools so that semiskilled personnel can understand and do them.

Employees are being taught to read and interpret engineering drawings, know and apply acceptance standards, identify aircraft materials, process necessary paper work, and use new tools and fixtures. They also are receiving instruction in methods of attachment, mathematics, elementary metallurgy, and hardness testing. Instruction in job method analysis, time and motion study, cost analysis, statistical control, lighting, and safety are also being given.

Quality control concepts
and techniques are changing
rapidly in the aircraft industry

Control

D. R. Archibald, Convair Division, General Dynamics Corp.

Excerpts from secretary's report of panel discussion on "Quality Control," held as part of the SAE Aircraft Production Forum, Los Angeles, Oct. 6, 1954.

3. Inspection Reliability is Being Improved

The inspection audit plant—one of the most significant innovations in recent years—is devised to measure and assure conformance to policy and procedure. The plan requires an independent group of men to reinspect systematically the results of inspection to make sure control is being exercised at the working level. Thus, quality control management knows from factual evidence, instead of opinion, that its organizations are functioning properly.

Another improvement in the quality control function is the improvement and accuracy of reporting on "first-article" production changes. Preplanned inspection charts, which are prepared from an analysis of the new inspection operation, reduces confusion when a new part or procedure is introduced to the production line. It also assures a skilled and complete inspection at a time when the most beneficial corrective action can be taken.

Process control also increases the reliability of inspection. The manufacturing process is studied to isolate the factor that causes variations in the part. Then controls are placed on these variables to assure consistent results.

4. Quality Control is Working More Closely with Design

The quality control department is supplying the engineering department with more information and recommendations. The designer uses them to eliminate many potential reliability weak points. For instance, the designer is being apprised of safety tolerance factors that must be added to allow for manufacturing and storage deterioration.

CONTINUED ON NEXT PAGE

The Experts

The material on quality control contained in this article is based on a panel discussion by the following experts:

Panel Leaders:

G. A. Covington,

Convair Division, General Dynamics Corp.

I. Dagan,

Rohr Aircraft Corp.

Panel Secretary:

D. R. Archibald,

Convair Division, General Dynamics Corp.

Panel Members:

J. W. Young,

North American Aviation, Inc.

J. Mannion,

Northrop Aircraft, Inc.

H. W. Hill,

Douglas Aircraft Co., Inc.

5. There is Better Liaison with Vendors and Subcontractors

To insure getting quality products, efforts are being made to obtain better communications between the prime and the subcontractor. Facility survey programs and vendor certification help accomplish this. Quality control departments are guiding vendors in an effort to establish compatible inspection programs. As a first-run product is received, it is inspected or acceptance-tested according to the listed classified characteristics. A first-article check is made to insure conformance with specifications. A critical review is made to see if it will function as intended. A system of two-way feedback is initiated to purify design, manufacturing methods, and quality control methods.

When a vendor is being selected, the past performance of the company, its attitude in processing complaints, and the time lapse in taking corrective action are as important as getting a low bid.

6. Quality Control Data are Being Disseminated More Quickly

Some companies are using "trend charts" with concise summaries and recommendations so that supervisors can read and grasp the information in a few minutes, and take necessary corrective measures easily. If this data is expressed in dollars instead of percentages or number of scrapped pieces, it gets much more effective response from labor and management.

Publicizing the need for building quality into a company's product seems to be paying off. Many companies distribute to employees small folders on quality control, tied in with the idea that more sales and job security come through less costly and higher quality products. Stories in house organs and posters are other ways of continually keeping quality control before employees.

7. Contact Between Control Personnel and Customer is Increasing

Quality control personnel are helping in the selling job. By visiting customers and obtaining their opinions of the quality of the product delivered, something can be done about complaints immediately. It also shows a personal interest in the customer and in the product being delivered, and instills a feeling of confidence in the customer.

8. New Methods are Being Used to Evaluate Product Quality

In addition to normal inspections, a two-phase system for evaluation is being used in one company:

1. A comprehensive inspection is made from maintenance, accessibility, producibility, design improvement, and quality assurance points of view, to detect and eliminate all potential deficiencies at the earliest and most economical point.

2. Then a review and analysis of all functional deficiencies discovered on test flights are made. All errors are isolated to indicate where further engineering test and design improvements are desired. Also, service reports are reviewed and placed in the feedback system.

9. Paper Work is Being Reduced

Although records are a natural and essential function of quality control, much time and money are being saved by periodically reviewing forms and systems. Unwarranted duplication is being eliminated, and forms simplified.

One company has considered using tabulating machines, but found no advantages which would offset the added costs. However, data from departments that use business machines—and can support them—are used.

There is also some work being done with the military services to simplify and unify paper work specifications and procedures. For instance, a standard form to be used by all branches of the services for acceptance of aircraft is being sought.

10. Procurement and Stock-piling of Raw Materials are Being Improved

Aircraft industry control committees are working out means to standardize raw material handling. One such plan is "birthmarking." Eleven ferrous and nonferrous alloys will be marked uniformly from the mill right through to the finished product. It will save money hitherto lost because it was too expensive to identify and salvage expensive alloys that are sold with mixed scrap.

(The report on which this article is based is available in full in multilith form, together with reports of nine other panel sessions at the SAE Aeronautic Production Forum. This publication, SP-309, is available from the SAE Special Publications Department. Price: \$2.00 to members, \$4.00 to nonmembers.)

1955 BUCKENDALE LECTURE . . .

will be offered in November by SAE President Rosen at Chicago.



C. G. A. Rosen

DR. C. G. A. ROSEN, SAE president, consulting engineer to the president, Caterpillar Tractor Co., has been chosen to deliver this year's Buckendale Lecture.

Characteristically looking into the future, President Rosen will discuss, "The Role of the Turbine in Future Vehicle Powerplants." His lecture will be given at a dinner meeting of Chicago Section in the Chicago Hotel Knickerbocker, Tuesday, Nov. 15, 1955, designated as President's Night.

The program will be directed especially toward young engineers. Developing the latent abilities in young men was of sincere interest to L. Ray Buckendale.

One objective of the lecture is to provide young engineers with up-to-date turbine information not generally available in textbooks.

1955 SAE GOLDEN ANNIVERSARY NATIONAL MEETINGS . . .

August 15-17
West Coast Meeting
Hotel Multnomah, Portland,
Ore.

September 12-15
Tractor Meeting and
Production Forum
Hotel Schroeder, Milwaukee
Wis.

October 11-15
Aeronautic Meeting
Aircraft Production Forum,
and Aircraft Engineering
Display
Hotel Statler, Los Angeles, Calif.

October 31-November 2
Transportation Meeting
The Chase, St. Louis, Mo.

November 2-4
Diesel Engine Meeting
The Chase, St. Louis, Mo.

November 9-10
Fuels and Lubricants Meeting
The Bellevue-Stratford
Philadelphia, Pennsylvania

1956 SAE National Meetings . . .

January 9-13
Annual Meeting
The Sheraton-Cadillac Hotel
and Hotel Statler, Detroit,
Michigan

March 6-8
Passenger Car, Body
and Materials Meeting
Hotel Statler
Detroit, Mich.

March 19-21
National Production Meeting
and Forum
Hotel Statler, Cleveland, Ohio

April 9-12
Aeronautic Meeting
Aeronautic Production Forum,
and Aircraft Engineering Display
Hotel Statler, New York, N. Y.

June 3-8
Summer Meeting
Chalfonte-Haddon Hall
Atlantic City, New Jersey

Leaders of Tractor Production Forum

J. E. DeLong (left), Sponsor of the 1955 SAE Tractor Production Forum, and A. A. Herzberg, General Chairman of the Forum, have completed plans for this fifth annual Forum, to be held in Milwaukee on September 12. De-

Long is president of Waukesha Motor Co. and Herzberg is plant manager.

Chairman Herzberg announces a seven-panel program, on topics of current interest to manufacturing men. Outstanding production and manufacturing management men from the Midwest will be on hand to answer questions and discuss problems asked by the audience.

Indications are that the Forum will attract good representation from the tractor and earthmoving industries, automotive plants, parts makers, and metal-working shops, as it has done in the past four years.

The Forum is being held in conjunction with the SAE Golden Anniversary Tractor Meeting. The three days following the Forum, September 13-15, will be devoted to technical sessions.



J. E. DeLong



A. A. Herzberg

SAE GOLDEN ANNIVERSARY

TRACTOR PRODUCTION FORUM AND MEETING

September 12-15, Hotel Schroeder, Milwaukee



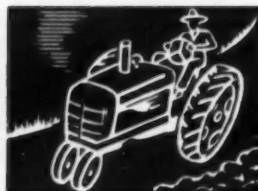
MONDAY, SEPT. 12—Production Forum featuring 7 informal panels on tools, quality control, gear making, supervisory talent, control of indirect costs, welding, and production control.

TUESDAY, SEPT. 13—For the earthmoving equipment man, 4 technical papers on brakes, torque converters, maintenance, twin power.



WEDNESDAY, SEPT. 14—Papers on designed-in safety, a self-propelled hillside combine, and tractor tires and transmissions—plus dinner starring R. S. Stevenson, Allis-Chalmers' president.

THURSDAY, SEPT. 15—Morning session on latest in diesel and spark-ignition tractor engines. Afternoon devoted to news of implements.



'55 SAE Council at Peoria

THE SECOND meeting of the 1955 Council was held in Peoria, Ill., on April 14, and a roving camera caught the members and guests just before they attended a luncheon with top executives of the Caterpillar Tractor Co.

At President Rosen's invitation, William Blackie, executive vice-president of Caterpillar, told the

Council of his impressions of industry and economics in Brazil, Australia, and Great Britain.

The Council convened again in Atlantic City on June 16.

Next meeting is scheduled for September 14, during the SAE National Tractor Meeting and Production Forum in Milwaukee, Wis.



Left to right: G. W. Mork, Heil Co.; R. F. Kohr, Ford Motor Co.; M. C. Horine, Mack Mfg. Corp.; F. G. Shoemaker, SAE Councilor.



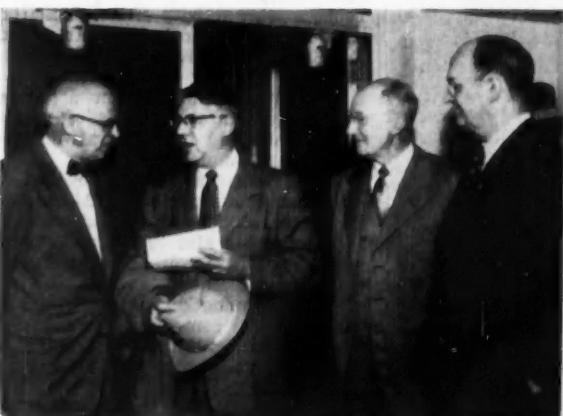
Left to right: Robert Gardner, American Trucking Associations, Inc.; P. A. Miller, Ford Motor Co.; M. P. Jolley, Canadian Acme Screw and Gear, Ltd.; T. B. Rendel, Shell Oil Co.



Left to right: W. G. Nostrand, Winslow Engineering Co.; R. T. Mees, Caterpillar Tractor Co.; J. W. Sydnor, Caterpillar Tractor Co.; J. W. Bridwell, Caterpillar Tractor Co.; J. D. Redding, Westinghouse Electric Corp.



Left to right: Randall Roman, Caterpillar Tractor Co.; F. A. Robbins, Koppers Co., Inc.



Left to right: C. G. A. Rosen, Caterpillar Tractor Co.; L. B. Neumiller, Caterpillar Tractor Co.; A. T. Brown, Caterpillar Tractor Co.; H. S. Eberhard, Caterpillar Tractor Co.



Left to right: William Blackie, Caterpillar Tractor Co.; John A. C. Warner, SAE secretary and general manager.

TECHNICAL COMMITTEE

Progress

SAE Seat Belt Group

Meets With Air Force Researchers

MEMBERS of the SAE Seat Belt Committee (below) visited Holloman Air Force Base last May. The Committee made the trip to confer with Lt.-Col. John P. Stapp (shown below), who is famous for his extensive work on physiological effects of high decelerations, particularly with himself as subject in a rocket-propelled sled.

The group also learned about Air Force test methods and instrumentation.

Members of the Committee participated in demonstrations in which they

were subjected to decelerations of about 6 g. They also saw a car crash into a barrier at 45 mph. Dummies in the car were with and without seat belts.

Members of the Committee are, left to right: Chairman A. L. Haynes, Ford Motor Co.; Rodney Craves, American Motors Corp.; David Baldwin, National Safety Council; Lt.-Col. Stapp; Don Blanchard, SAE Staff; H. K. Gandelot, GMC; Roy Hausler, Chrysler Corp.; W. F. Sherman, AMA; and D. J. Schrum, Studebaker-Packard Corp.



Technical Board OK's Appointments

AT its meeting on June 14, the SAE Technical Board approved a number of appointments made by the Board's Executive Committee since its previous meeting on Jan. 13. Included were the appointments of:

A. H. Smith, chief metallurgist, Cadillac Motor Car Division, General Motors Corp., as chairman of the SAE Iron and Steel Technical Committee for 1955.

R. P. Trowbridge, assistant standards engineer, General Motors Corp., as SAE representative on ASA Sectional Committee Y14—Drawing and Drafting Room Practice, and on the ASA Graphic Standards Board, succeeding W. A. Siler, resigned.

R. F. Kohr as sponsor of the SAE Motor Vehicle Seat Belt Committee.

L. L. Beltz, Ford Motor Co., as SAE representative on ASA D7—Safety Inspection of Motor Vehicles, succeeding T. J. Carmichael, resigned, and appointment of K. A. Stonex, General Motors Proving Ground, as alternate to Mr. Beltz.

S. R. France, Inland Manufacturing Division, General Motors Corp., as SAE representative on ASA Sectional Committee B52—Classification of Materials for Tools, Fixtures and Gages, succeeding L. A. Danse, resigned.

Carbide Steel Specs Under Development

WORK is under way on development of physical property specifications of cutting-tool and die grades of carbide steels. It is being carried out by Division XXXIV—Carbides for Cutting Tools, a joint activity of the SAE Iron and Steel Technical Committee and the SAE Nonferrous Metals Committee.

Members of the division are now evaluating several methods of measuring grain size by cooperative tests on similar samples.

The division has already decided to recommend adoption of ASTM tests on specific gravity, hardness, and porosity. It has decided also to use a diamond wheel test for wear and a fine-particle-blast test for cracks.

Feeling among division members is that chemical composition determination is so difficult to make that it is not worth while to include among the specifications.

The division will try, however, to work out a classification of grades of carbide steels—the classification to include only those grades required by

two or more users. It will try also to define cuts, so that a term like "roughing cut—severe" will mean the same throughout the automotive industry.

Serving on Division XXXIV are Bruce Wright, Buick, chairman; G. F. Bush, Ford; C. G. Chambers, General Motors; W. E. Day, Jr., Mack Mfg.; A. S. Jameson, International Harvester; W. W. Sellers, Caterpillar Tractor; and H. H. Zurburg, Chrysler.

Drafting Group to Set Needs for Microfilming

HOW do you prepare a drawing so that it'll be suitable for microfilming? That's what the SAE Automotive Drafting Committee is trying to find out. It recently set up a subcommittee to do this.

Aim of the new group, headed by M. L. Carpentier, of Chrysler Corp., is to come up with standards covering height of letters, quality of lines, and other drawing features. This is to assure legibility and clarity when the microfilm is blown up to size.

The automotive industry has a special interest in microfilming and is using the technique. It's a real space-saver when it comes to service parts drawings, which may not have to be used for 10 or 15 years.

The new subcommittee has invited the participation of the SAE Aeronautical Drafting Manual Committee in its program. It is also checking drawing requirements established by the Navy and the Air Force. Both services use microfilming extensively.

Aero Materials Specs Reviewed by Industry

DRAFTS of twenty-five SAE Aeronautical Materials Specifications are currently being circulated to industry for comment and criticism by the SAE Aeronautical Materials Specifications Division.

Copies of all these specifications are available for review from the SAE Aeronautical Department, 29 West 39 Street, New York 18, N. Y.

The specifications under review are:

- AMS 2675A—Nickel Alloy Brazing;
- AMS 3200C—Synthetic Rubber, Hydraulic Fluid (Petroleum Base) Resistant (55-65);
- AMS 3204D—Synthetic Rubber, Low Temperature Resistant (25-35);
- AMS 3205D—Synthetic Rubber, Low Temperature Resistant (45-55);

• AMS 3237A—Synthetic Rubber, Phosphate Ester Resistant, Butyl Type (35-45);

• AMS 3238A—Synthetic Rubber, Phosphate Ester Resistant, Butyl Type (65-75);

• AMS 3239A—Synthetic Rubber, Phosphate Ester Resistant, Butyl Type (85-95);

• AMS 4090—Aluminum Alloy Tubing, 1Mg-0.6Si-0.25Cu-0.09Cr (6062-H11);

• AMS 4120D—Aluminum Alloy Bars, Rolled, 4.5Cu-1.5Mg-0.6Mn (2024-T4);

• AMS 4152F—Aluminum Alloy Extrusions, 4.3Cu-1.5Mg-0.6Mn (2024-T4);

• AMS 4775A—Brazing Alloy, Nickel Base—4Si-16.5Cr 4Fe-3.8B;

• AMS 4890—Copper-Beryllium Alloy Castings, Precision Investment, 2Be-0.4Co-0.3Si;

• AMS 5201—Magnetic Alloy Sheet and Strip, Nickel—Iron Alloy;

• AMS 5205—Magnetic Alloy, Nickel—Iron Alloy;

• AMS 5516E—Steel Sheet and Strip, Corrosion Resistant 18Cr-8Ni (SAE 30302), Cold Rolled—36,000 psi Yield;

• AMS 5573A—Tubing, Seamless, Corrosion and Heat Resistant 17.5Cr-12.5Ni-2.3Mo (SAE 30316);

• AMS 6427A—Steel, 0.8Cr-1.8Ni-0.4Mo-0.07V;

• AMS 7452E—Bolts and Screws, Steel, Alloy, Heat Treated—Roll Threaded;

• AMS 7456C—Studs, Steel Alloy, Heat Treated—Roll Threaded;

• AMS 7470B—Bolts and Screws, Steel, Corrosion Resistant Heat Treated—Roll Threaded;

• AMS 7490C—Rings, Flash Welded, Austenitic Corrosion and Heat Resistant Steels and Alloys;

• AMS 7493C—Rings, Flash Welded, Non-Austenitic Corrosion Resistant Steels;

• AMS 7496B—Rings, Flash Welded, Carbon and Low Alloy Steels;

• AMS — Welding Electrodes, Coated, Low Alloy, Low Hydrogen;

• AMS — Magnesium Alloy Castings, Sand, 3.3Th-0.8Zr (HK31A-T6), Solution and Precipitation Treated.

Technishorts . . .

ERDL IS HOST—Members of the Hydraulic Power Controls Subcommittee of the SAE Construction and Industrial Machinery Technical Committee visited the Army Corps of Engineers Research and Development Laboratories at Fort Belvoir, Va., June 30. The group inspected heavy earthmoving equipment at the Engineer Proving Ground and heard talks on the Laboratories' hydraulics work.

TRANSMISSION SEALS—Six makes of cars use transmissions employing lip-type seals of nearly identical cross-section and dimensions, the Subcommittee on Controls of the SAE Hydrodynamic Drive and Transmissions Committee has found. Therefore, the Committee's Design Standards Subcommittee intends to investigate possibility of standardizing these seals.

The seals serve on certain servo pistons and clutch pistons where low friction drag is desired or where conditions such as relative expansion, out-of-roundness in stamped cylinders, or tilting pistons articulated directly on servo levers are used. Seal cross-section and piston-groove dimensions appear to be about the same for a variety of diameters. This gives hope that standardization would be practical.

The Design Standards Subcommittee will consider also take-off openings for temperature-indicating devices, cooler line openings for mounting flanges, and oil seal rings.

SERRATED SHAFT ENDS—The SAE Recommended Practice on Serrated Shaft Ends has been reinstated. It formerly appeared in SAE Handbook but was discontinued after the 1946 edition. This reinstatement action was taken at the request of the SAE Construction and Industrial Machinery Technical Committee. Aircraft manufacturers have also indicated that they still refer to the document.

The SAE Recommended Practice on Serrated Shaft Ends is intended for use on attachments and accessories for old equipment only. For new applications, designers are referred to the SAE Standard on Involute Serrations.

HAROLD NUTT, 1954 SAE vice-president representing Passenger Car Activity, has been elected president and general manager of the Borg & Beck Division of Borg-Warner Corp.

Nutt is a veteran automotive executive. He joined Borg & Beck in late 1930 as director of engineering. He was elected vice-president in charge of engineering in 1946. By 1954 he had been promoted to vice-president and general manager.

KENNETH R. HERMAN has been elected second vice-president of the Engineering Society of Detroit. He is executive vice-president, general manager, and director of Vickers, Inc., as well as vice-president of Sperry Corp.

Other new officers of the Society are **WILLIAM H. GRAVES**, secretary, vice-president of engineering for Studebaker-Packard Corp.; and **FRED J. WALLS**, treasurer, manager of Detroit Technical Section of the Research and Development Division, International Nickel Co.

PAUL E. TOBIN has been appointed general sales manager of the White Motor Co. truck division. He has been regional manager of the North Atlantic region, with headquarters in New York City, since 1942.

JOSEPH E. ADAMS, director of purchasing and planning of White Motor Co., has been named general manager of manufacturing of White Truck Division. The announcement was made by **J. N. BAUMAN**, executive vice-president in charge of the Division.

Adams joined White Motor in 1944 and soon after was appointed director of material control. He held this position until 1950 when he was made director of purchasing and planning.

CARL J. EATON, assistant director of research for Champion Spark Plug Co., has been named director of engineering. **L. R. LENTZ**, of the engineering department, has been appointed assistant director.

Both men will report to **ROBERT K. CHRISTIE**, who became vice-president in charge of engineering and research in January. The announcement was made by **R. A. STRANAHAN, JR.**, president of the company.

L. R. (Mike) HACKNEY will head a new Military Relations Department at Fairchild Aircraft Division, Fairchild Engine & Aircraft Corp. He has been executive vice-president of Transport Air Group, Inc., the Association of Airlift and Airfreight Carriers.

WALTER G. BAIN has been elected to the board of directors of Republic Aviation Corp. He is vice-president and general manager of the corporation. He came to Republic in 1953 as special assistant to the president.

About SAE Members



Nutt

Herman

Graves

Walls



Tobin

Adams

Eaton

Lentz



Hackney

Sheldrick

Frederick

Truxell, Jr.

LAWRENCE S. SHELDRICK has been named technical assistant to the general manager of Detroit Diesel Engine Division, GMC. He had been serving as director of Engineering.

CHARLES W. FREDERICK, who has been assistant chief engineer of Chevrolet Division since 1952, replaces Sheldrick as engineering director.

CLYDE W. TRUXELL, JR., was appointed works manager of the Division. He has been director of engineering and manufacturing, Aeroproducts Operations—Allison Division.

LESTER L. COLBERT, president of Chrysler Corp. predicted recently: "Automobiles of tomorrow may require manual guidance only to place them in the proper lane of a superhighway network, where electronic controls could take over."

RICHARD A. TEAGUE has been named director of styling for Packard Division of Studebaker-Packard Corp. He has been chief stylist for Packard cars for more than four years.

Teague's new responsibilities are part of Studebaker-Packard's program separating styling responsibilities for each of the company's lines of cars and trucks. He is part of a newly established styling division.

GEORGE A. TINNEMAN, vice-president and director of Tinnerman Products, Inc. and president and chief executive of Dominion Fasteners, Ltd., is now president of a new Cleveland company. He heads Pneuma-Serve, Inc., introducing a new device which automatically feeds screws to power screwdrivers.

JOHN P. KELLY, formerly design engineer for Waukesha Motor Co., has been appointed chief draftsman of the Engineering Department. He succeeds **LLOYD M. KANTERS**, who has retired after 40 years' service with the company, and will be in charge of the drafting department and a number of other related activities.

HARLEY NEWCOMB has joined Soreng Products Corp., Schiller Park, Ill., as manager of automotive sales. Prior to joining Soreng, Newcomb's

efforts were concentrated on the development of the automotive switch program for the Wade Electric Products Co., Sturgis, Mich.

CHARLES T. LANGLEY has joined Mather Spring Co., Toledo, as special resident engineering representative in Detroit. He was assistant superintendent of the Gear Division of the Timken Detroit Axle Co.

Langley is 1954-1955 Detroit vice-chairman for Junior Activity. He has been active in SAE committee work.

KARL A. ROESCH is now general manager of White Motor Co.'s Autocar Division.

Since 1954, Roesch has served as director of service, with responsibility over parts sales and service. He first joined White Motor in 1928 in a sales position.

MARSHALL E. MUNROE has been appointed director of procurement of Massey-Harris-Ferguson, Inc., Racine, Wis. He has been director of procurement activities of the Detroit operation of the company.

EDGAR L. CONN has been appointed manager of manufacturing of the South Wind Division of Stewart-Warner Corp. He had been works manager of Fairbanks-Morse Co., Beloit, Wis., prior to his association with South Wind.

C. M. SCALES, formerly staff engineer at Plymouth Division, Chrysler Corp., is now director of product planning for the Division. He had been in charge of engineering publications for the Engineering Division.

ROY A. JOHNSON, formerly assistant chief engineer, Tractor Division, Allis-Chalmers Mfg. Co., has been appointed Midwest manager of sales of the Kendrick Mfg. Co. of Detroit, Mich. Johnson will operate from the Kendrick regional office at Mukwonago, Wis.

GEORGE H. COMPTE, assistant to the vice-president and secretary of Ford Instrument Co., Division of the Sperry Corp., is now with the United States Department of Commerce. He has been appointed Consultant on Synchros and Servo Devices to the Electrical Equipment Division, Business and Defense Services Administration. He will serve for a period of at least six months under a BD3A plan whereby experienced industry personnel volunteer their services for business and defense programs.

H. R. STEDING, chief engineer—Executive Staff, Chrysler Corp. Engineering Division, stated that "this year's automobiles are the safest ever produced because of the industry's unending and vigorous efforts to manufacture an increasingly better product."

In an address at the annual meeting of the Ontario Traffic Conference in Windsor, Steding stated that safety in automobiles is a prime objective both in engineering and design.

GEORGE BOSWINKLE has accepted a position with the Research & Development Department of Whirlpool Corp. He is serving as design engineer.

Previously he was chief engineer of the Filter Division of Michiana Products Corp.



Kelly



Newcomb



Langley



Roesch



Munroe



Conn



Scales



Johnson



Compere



Hoiby



Wylie



Skeist

JAMES C. HOIBY is now vice-president in charge of engineering for D. W. Onan & Sons, Inc., Minneapolis manufacturers of electric generating equipment. Formerly chief engineer of the firm, Hoiby has been associated with the company since 1934. In his new position, he will be in charge of the newly reorganized Engineering Division, including both Production Engineering and Development and Design.

FRANK W. WYLIE has been promoted to the position of public relations manager of Dodge Division, Chrysler Corp. He has been manager of special events for Dodge for the past year and has had extensive public relations experience. He joined Chrysler Corp. in Detroit in 1948 and was assigned to handling exhibits of the Central Engineering Division.

S. MERRILL SKEIST has been elected vice-president—Contracts, and a member of the board of directors of Polarad Electronics Corp. He was formerly vice-president of the W. L. Maxon Corp. and a member of the board of Langevin Mfg. Corp.

As vice-president of Polarad, he will be in charge of government contract relations and commercial sales.

RALPH L. BAYLESS has been named chief engineer of Convair Division, General Dynamics Corp. He has been assistant chief engineer in charge of research, development, and technical sections at Convair.

As chief engineer, Bayless will have charge of the company's experimental factory, experimental flight test operations, and military sales and service engineering.

1934 SAE PRESIDENT DELMAR G. ROOS, Delmar G. Roos & Associates, and **ALEXANDER ZEITLIN**, Birdsboro Steel Foundry & Machine Co., are now serving as directors of the newly organized company, Gemco, Inc., New York City.

The new company will provide a wide range of services to industrial and business enterprises particularly in the field of metal working and durable goods.

JOHN G. MOXEY, JR., assistant director of Sun Oil Co.'s Research and Development Department, told the Philadelphia Section of the American Society of Lubrication Engineers that the motoring public can now buy an oil with both winter and summer grade characteristics.

Speaking on "Multi-Grade Oils," Moxey commented that "five advantages offered by multi-grade oils are good starting, low friction, better fuel economy, reduced oil consumption, and less tendency to form carbon in the high compression engines we have today and expect in the future."

He has been a member of SAE since 1937 and served as chairman of Philadelphia Section in 1946-1947. In 1952 he was SAE vice-president representing Fuels and Lubricants.

MILTON R. REARICK is now president and general manager of Sandusky Mfg. Co., Inc., Sandusky, Mich. He had been development engineer for the Development Division of Aluminum Co. of America.

J. D. DICKERSON has been appointed to the staff of the Central Operating Department of Crucible Steel Co. of America. He has been chief metallurgist at the company's Midland, Pa. Works.

N. J. RAKAS has been appointed director of research and development for National Automotive Fibres, Inc. He has been sales engineer for the company since 1948.

WILLIAM J. NANFELDT, World Bestos Corp., has been elected president of Friction Materials Standards Institute, Inc. Serving with him on the board of directors are **FREDERICK C. WEYBURN**, Marshall-Eclipse Division, Bendix Aviation Corp., and **WILLIAM J. VACHOUT**, Molded Materials Division, Carlisle Corp.

JAMES C. ZEDER, 1950 SAE president and vice-president of Chrysler Corp. in charge of engineering activities, has been appointed to the board of trustees of the Air Pollution Foundation.

Zeder is at present serving on the SAE Finance Committee.

JAMES E. GETZ is now serving with the U. S. Army as a mechanical engineering research assistant in the Ballistics Research Laboratory, Aberdeen Proving Grounds, Md. He has been with the Research Department of Standard Oil Co. of Indiana.

LUDWIG T. STOYKE is now assistant chief engineer with Lear, Inc., Lear-Romec Division, Elyria, Ohio. He had served in the same position with Hydraulic Division of Sunstrand Machine Tool Co., Rockford, Ill.

CHARLES L. CUTTER is now affiliated with Reeves Pulley Co. as design engineer. Cutter had been field engineer at Cummins Engine Co., Columbus, Ind.

RICHARD G. BOWMAN has been delegated new responsibilities as assistant chief engineer for production with Republic Aviation Corp. As assistant engineer since 1950, he had charge of various technical engineering groups. The wider scope of his new position will give him full charge of all engineering on production airplanes, including supervision of project sections and systems groups.

D. S. KIMBALL, JR., vice-president and general manager of Bendix-Westinghouse Airbrake Co., headed a discussion on "A New Look at Cost Reduction" during the Industrial Management seminar at Cornell University, June 14. The discussion covered areas other than direct labor.



LEWIS F. MOODY, JR., and **JOHN C. GIBB**, senior engineering representatives of Socony Mobil Oil Co., Inc., were honored at a recent diamond jubilee meeting of ASME in Washington, D. C. They were awarded bronze medals for the joint paper they presented at the Mexico City international ASME meeting in March, 1954.

The society noted their paper, "Factors Affecting Oil Drain Practices for Diesel Engines," as a worthy contribution to the advancement of the mechanical engineering profession.

DR. WILLIAM J. O'DONNELL is now assistant chief engineer for development and experimental with Republic Aviation Corp. He has served in Republic's Engineering Department for 15 years, the last ten as chief development engineer.

C. D. FLANIGEN has become chief engineer of the Utica Division of Bendix Aviation Corp. He takes over engineering direction of a specialized line of aviation accessories, including jet engine starters, air-turbine-driven accessories, air conditioning equipment, valves, oil separators, de-icing equipment, pumps, and other related devices manufactured at Utica.

1954 SAE PRESIDENT WILLIAM LITTLEWOOD has been elected as one of the alumni trustees at Cornell University. He is a past-president of the Cornell Society of Engineers, a director of the Cornell Aeronautical Laboratories, and served several terms as a director of the Cornell Alumni Association.

WELLWOOD E. BEALL, Boeing Airplane Co. senior vice-president, has received a centennial award from New York University's college of engineering. He was cited for "professional achievements and service to the common good." Beall is a 1930 graduate of the university.

ROBERT E. FIDLER, previously sales manager for the Portland plant of Thompson Products, Inc., has been appointed assistant division sales manager for the Rochester, Mich. Division of the company.

ERNEST J. KLIMCZAK has been appointed general manager of the Ahlberg Bearing Co. He was also elected vice-president at the last meeting of the board of directors.

Klimczak, formerly secretary and chief engineer of the company, joined Ahlberg in 1943 as tool engineer. The company produces ball bearings for engines, electric motors, and instruments used in the automotive and aircraft industries.

J. W. ARNOLD is now associated with Hydraulic Press Mfg. Co., Mount Gilead, Ohio, as vice-president in charge of manufacturing. He will play a major role in carrying out new company policies based on the decision that Hydraulic Press will continue as an independent company. He had previously served as general manager of Erie Engine and Mfg. Co., Erie, Pa.

GUSTAV W. CARLSON has retired as chief engineer of the Axle Division, Eaton Mfg. Co., as of July 1. He is a 35-year veteran at Eaton.

Carlson will continue with the Division as consulting engineer. He has become a nationally recognized authority on motor truck axle design. He is

especially renowned for his part in the development of the two-speed axle, the popularity of which has probably done more toward the rapid use of trucks in highway transportation than any other unit.

LOUIS B. PELTIER has been named West Coast manager of contractual engineering for United Aircraft Products, Inc. He has taken over the UAP North Hollywood office as of June 1.

Peltier has been chief project engineer of radial helicopter engines at Continental Aviation and Engineering Corp., Detroit.

KENNETH A. HONROTH has been elected president of Freeway Washer & Stamping Co., Cleveland. He is a founder of the corporation and has been serving as secretary and treasurer.

GEORGE STASIE is now employed by the Ford Motor Co., Detroit Truck Plant, Highland Park, Mich., in the capacity of a production contact engineer associated with the Resident Engineering Office. He had been associated with Timken Detroit Axle Co.

DR. ROBERT F. THOMSON, head of Metallurgy Department of General Motors Research Laboratories Division, has been awarded the John A. Penton Gold Medal by the American Foundrymen's Society.

The award, one of the Society's highest honors, was presented for "outstanding contributions to the society and the industry in foundry research, particularly in the field of light metals."

FRANK MORGAN, owner of Frank Morgan Co., Marysville, Calif., has recently published the "Hot Cam Handbook" on how to choose the right grind and make it perform, with pointers on valve modification.

MARVIN R. ANDERSON, executive vice-president of Michigan Tool Co. of Detroit, has been elected president of the American Gear Manufacturers Association. AGMA is a trade association of firms in the gear industry and allied gear production equipment.

ANDERS PETTERSON is now a mechanical engineer for the Cross Co., Detroit, Mich. He did research engineering for the Ford Motor Co.

FRED N. DICKERMAN, formerly director of engineering of Chance Vought Aircraft, Inc., has been named chief preliminary design engineer of the Georgia Division, Lockheed Aircraft Corp. He will direct the activities of the aerodynamic, preliminary design, and sales engineering departments of Lockheed's Marietta, Ga. plant.



Fidler

Klimczak

Arnold

Carlson



Peltier

Honroth

Stasie

Thomson

HENRY LOWE BROWNBACK, technical counsel, Regie Nationale des Usines Renault, Billancourt, Seine, France, has just been promoted to officer of the Legion of Honor by the French government.

GORDON A. SOSSICH is now serving as Transportation Operations Administrator, Transportation and Traffic Management Branch, Office, Chief of Ordnance, Department of the Army, Washington, D. C. He was formerly Chief, Inspection Branch, Transportation Materiel Command, Marietta, Pa.

HAROLD E. VICKERMAN is now associated with Kawneer Co., Niles, Mich. as project engineer in the Aircraft Division. Kawneer is primarily a fabricator of architectural aluminum. In addition, they fabricate aircraft subassemblies, canopies, flaps, ailerons, and fairings.

Vickerman was formerly engineering supervisor, A. O. Smith Corp. Rochester Works.

J. H. CARMICHAEL, president of Capital Airlines, Inc., has been appointed as chairman of the Transportation and Communication Committee of the Chamber of Commerce of the United States for the year 1955-1956. He is also a vice-president and a director of the Chamber.

EDWARD GRAY, who for the last year has directed Chevrolet Motor Division activities at the GM Proving Ground, has been named as assistant chief engineer in charge of production engineering.

Gray's duties at the Proving Ground will be taken over by **NELSON E. FARLEY**, director of the Vehicle Development Group.

HENRY N. FEDORCHUK has been elected secretary of the Junior Section of the Engineering Society of Detroit for the year 1955-1956. Fedorchuk, a mechanical engineer, is with the Experimental Test Laboratory, Chevrolet Division, GMC.

HARLOW H. CURTICE, president of General Motors Corp., received an honorary Doctor of Engineering degree at the 111th commencement of the University of Michigan, June 11.

The degree was conferred in honor of "his contribution to the vitality of the nation and the health and happiness of its people."

"An envoy extraordinary to the free world," the citation continues, "Mr. Curtice toured the industrial centers of Europe, bringing to those lagging economies help and the breath of life. He returned from a Europe which had increased respect for American business and American leadership."

The honorary degree of Doctor of Commercial Science has also been awarded to Curtice by Northeastern University. Presentation was made at commencement June 17.

Northeastern president Carl S. Ell conferred the degree on this "business executive of international prominence, courageous builder of American industry, whose dynamic leadership as the president of a great corporation has had an impressive influence upon industrial practices throughout the world."

Said Ell to Curtice: "Your career, your philosophy of work, your versatility are in the best traditions of American enterprise, exemplifying the importance of persistent effort and realistic optimism."

CONRAD F. ORLOFF has been promoted to staff engineer in charge of production engineering. He has been resident engineer in Flint, Mich., for Chevrolet.

DOUGLAS E. PEASH has accepted a position as project design engineer with Boeing Airplane Co. of Seattle. He was design engineer with Ladish Co., Cudahy, Wis.

WILLIAM D. FERREULT, until recently managing editor of *American Aviation* magazine, has joined the Georgia Division of Lockheed Aircraft Corp., as a military sales representative.

PAUL E. HOVGARD has been named director of research and development of the Kellett Aircraft Corp., Camden, N. J. He had been Head of Helicopter Research, Department of the Navy, Bureau of Aeronautics, Washington, D. C.

A. B. GORMAN has been awarded the annual merit award of the Automotive Council of Los Angeles. He is president of the Private Truck Council of America, Inc.

The award is presented annually to the person "having contributed the most, on a national basis, to the motor transportation and trucking industry."

JAMES T. W. MOSELEY, previously chief engineer for the Carter Carburetor Corp. of St. Louis, has taken the position of vice-president and director of engineering with Hunter Engineering Co. of that city.

CHESTER E. PALMER, formerly vice-president and assistant general manager of Mechanics Universal Joint Division, Borg-Warner Corp., has been elevated to the post of executive vice-president.

HAROLD E. KOESTER has taken a position as project engineer with Grand Central Rocket Co., Redlands, Calif. He has been senior design engineer with Convair Division, General Dynamics Corp.

RALPH I. BATES has recently retired from Delco Products Division of General Motors Corp. after 40 years with the division.

Joining the original Dayton Engineering Laboratories Co. (Delco) as a service engineer on automotive electrical equipment, he served in various sales and engineering capacities. During the past four years he has been assistant chief engineer on hydraulics.

G. WILLIAM MOODY is now associated with Peterson Window Corp., Ferndale, Mich., as sales engineer. He had served in the same position with Rich Mfg. Corp., Battle Creek, Mich.

W. R. MACKENZIE has been named to direct the new Engineering Product Information Department of Chevrolet Division, GMC. The new unit will supply technical assistance and information from the engineering groups for advertising and sales promotion projects, as well as for animated product exhibits.

H. W. OVERMAN has become director of sales for the Brooks Equipment Co., Division of the Borg-Warner Corp. His temporary offices are in Knoxville, Tenn.

Overman has been manager of the Materials-Handling Division of American Pulley Co.

MAJOR REUBEN H. FLEET (USA, retired) of San Diego, Calif., pioneer aircraft manufacturer and former president of the Institute of Aeronautical Sciences, was honored for his long service to the Institute and the aviation industry. **ROBERT E. GROSS**, president of IAS and of Lockheed Aircraft Corp., presented him a Certificate of Appreciation before a distinguished audience of engineers and executives of the aircraft and air transport industries.

A. W. HERRINGTON, chairman of the board of Marmon-Herrington Co., Inc., and 1942 President of SAE, has completed negotiations for the purchase of substantially all of the common stock of the Cardox Corp., Chicago. Cardox will be operated as a separate corporation. It manufactures chemicals, mining equipment, fire-fighting equipment, and agricultural equipment.

VAL J. ROPER, Lamp Division, General Electric Co., and **HARRY C. DOANE**, Buick Motor Division, GMC, served as members of the industry delegation of the Automobile Manufacturers Association to the international meeting of the International Commission on Illumination at Zurich, Switzerland. They arrived in Zurich in time for the Brussels Working Party session, June 12.

THOMAS G. WHITTINGHAM has been promoted to assistant sales manager of Vinco Corp., Detroit. He has served in engineering and sales with the firm since 1951.

PAUL W. EELLS is now factory representative with Thermoid Co., Trenton, N. J. He had been vice-president and director of Le Roi Co.

Eells was chairman of Milwaukee Section in 1933-1934.

FRANK JARDINE has retired from his position as technical consultant to Aluminum Co. of America. He has been known as one of the nation's outstanding pioneers in automotive applications of aluminum.

A veteran of 37 years service with Alcoa, Jardine was for many years manager of the Cleveland branch of the company's development division. This group has made numerous contributions to better automotive design through the proper application of aluminum.

On March 1, 1953, Jardine retired from his post as manager of the Cleveland development division to become a special consultant.

ROBERT E. GERBER has become assistant chief engineer with Insley Corp. He has been serving as design engineer with the firm.

WELLINGTON R. GRAHAM was presented a diamond service pin by the president of Purolator Products, Inc., to mark his completion of 30 years of service with the pioneer filter manufacturer.

Graham, administrative engineer at Purolator, joined the company on June 2, 1925, and had served as chief draftsman and assistant chief engineer before being assigned to his present position.

Obituaries

VALENTINE GEPHART

Valentine Gephart, president of Valentine Co. and retired Colonel of the U. S. Marine Corps, died recently. He had been an active member of SAE since 1925.

Gephart retired from the Marine Corps about three years ago to give his time to his industrial chemical firm, Valentine Co., Seattle, Wash. He had established the firm in 1924.

In 1926 Gephart was commissioned in the Marine Corps Reserve. He was recalled to active duty in 1940. During World War II he was assembly and repair officer at Pasco and later commanding officer of Air Base Group 2 in San Diego. In 1946 he received the Legion of Merit. He became a colonel in May, 1944.

Gephart served as Northwest Section chairman of SAE Placement Committee and had just recently been elected to the post of vice-chairman of the Sections Committee. He was also active in the American Chemical Society, the University Craftsman Council of Engineers, and the Society of Military Engineers.

DR. CHARLES R. SHORT

Dr. Charles R. Short, president of Citizens Bank of Clermont, Fla., died May 8. He had been one of the SAE pioneers, having joined the Society in 1910.

Besides serving as president of the Citizens Bank, Short was research engineer in his Florida Industrial Laboratory, Inc. He was chief mechanical research engineer at General Motors Corp. He had been associated with that corporation for more than 35 years.

Dr. Short is well known for his many inventions. He had 388 patented. His latest invention was the Short Process Decorticator, a machine to process ramie, a fiber-like plant used in making cloth.

Since moving to Florida, Dr. Short had done extensive work in soil sterilization, water hyacinth control, and citrus experiments. In 1945 he set up the Short Experimental Grove as a citrus laboratory. The 20-acre grove was later purchased by the Soil Science Foundation of Florida.

WALTER L. GOODMAN

Walter L. Goodman died May 23. He was manager of the Transportation Department, General Petroleum Corp., Los Angeles.

He was born in Parsons, Kan., April

19, 1893. He attended public schools in Parsons and later studied business management at Coffeyville Business College, Kan.

Goodman started his career in the petroleum business in 1914, joining Gulf Refining Co. as shop foreman. He moved to General Petroleum Corp. in 1922 and remained with that company until the time of his death. He had become manager of the Transportation Department in 1950.

Active in technical organizations, Goodman had held full membership in the Automotive Council and the Automotive Transportation Management Group.

PAUL E. LEWIS

Paul E. Lewis, assistant chief engineer at Leece-Neville Co., Cleveland, died Jan. 12. He was associated with Leece-Neville since 1942.

After studying chemical engineering at Ohio State University, Lewis started his career as a chemist with United States Gypsum Co. in 1925. He moved to American Temperature Indicating Co. as a salesman in 1927.

From 1928 to 1937 he served with Electric Auto-Lite Co. in the position of foreman. From then until he started with Leece-Neville, he was a salesman for Prudential Insurance Co.

JOSEPH E. BUTZ

Joseph E. Butz died of a heart attack early in June. He was sales engineer with Muskegon Piston Ring Co.

Butz had been employed as engineer with Muskegon Piston Ring Co. for 25 years. He had been in retirement for six years.

He operated one of the first garages in Dayton, and was later associated with the Dayton Engineering Laboratories Co., the Dayton Wright Aircraft Co., and the General Motors Research Laboratories.

Butz was born in Piqua, Ohio in March, 1879. He had been a member of SAE since 1923.

HARRY J. ERICKSON

Harry J. Erickson, retired engineer in Seattle, Wash., died June 15. He had been business analyst for the Office of Price Stabilization in Seattle in 1953.

Erickson was born in Dows, Iowa in 1895. He had studied at the University of Washington and Smith Institute in Chicago. He joined SAE in 1944.

He was vice-president and general manager of Yellow Cab Co. and Gray

Line Tours, Inc. from 1919 to 1941. He then established the H. J. Erickson Distributing Co. He was vice-president and general manager of the Veterans Transit Corp. in Los Angeles and then went into partnership with Seals Oil Co., Seattle. In 1953 he joined the Office of Price Stabilization in Seattle.

DONALD H. MERRY

Donald H. Merry, manufacturing manager, Bridgeport-Lycoming Division, Avco Manufacturing Corp., died May 26. He was 35.

Merry had been associated with Bridgeport-Lycoming since 1951. He had served in coordinating manufacturing procedures. Previous to this service with Bridgeport-Lycoming, he was on special assignment in 1950-1951 with Kaiser-Frazer Engine Division. He had also served with Ford Motor Co. as production engineer at the Rouge plant.

His first position in his engineering career was that of general foreman with Packard Motor Car Co. in Detroit.

CHARLES DEERE WIMAN

Charles Deere Wiman, president of Deere & Co., Moline, Ill., died May 12.

Wiman was great-grandson of the founder of Deere & Co., a farm equipment manufacturing firm. He first joined the firm in 1915. By 1924 he became vice-president and five years later was elected president.

He became director of the farm machinery and equipment division of the War Production Board during World War II.

Wiman held directorships in the Continental Illinois National Bank and Trust Co. of Chicago; the Chicago, Rock Island & Pacific Railroad; and the Hilton Hotels Corp.

GUSTAV A. LILLIEQVIST

Gustav A. Lillieqvist, research director for American Steel Foundries, Chicago, died of a heart attack May 31. He was known internationally for his contributions to the field of metallurgy.

Lillieqvist attended Polytechnical Institute of Zurich and the University of Berne, Switzerland, receiving his Ph.D. in Chemistry in 1924 from Berne. He was born in London and came to the United States in 1924.

In the same year he was hired as a chemist at the Granite City, Illinois, Works of American Steel Foundries. In 1927 he was transferred to the re-

search laboratory in East Chicago, Ind. He served there until 1941 when he was appointed assistant works manager and chief metallurgist of the Indiana Harbor Works. In 1943 he became research director for the company.

He has served on many committees of the Steel Founders' Society of America, the American Foundrymen's Society, the American Society for Metals, the American Society for Testing Materials, and the American Institute of Mining and Metallurgical Engineers.

EGON G. BERG

Egon G. Berg, transmission equipment engineering manager, Barber-Greene Co., Aurora, Ill., died April 3.

He was born at Breslau, Germany in 1901 and attended the Technical University of Breslau. He received a degree in mechanical engineering. Later he took a course in highway engineering at the University of Minnesota.

Berg came to the United States in 1929, after leaving the Technical University of Breslau. He joined Barber-Greene and served until 1937 with that company. He then moved to Goodman Mfg. Co., served with Pioneer Engineering Works, and moved to Universal Engineering Co., before returning to Barber-Greene in 1946 as development engineer.

EARL W. SMITH

Earl W. Smith died April 26. He was president of Dixie Greyhound Lines, Inc., Memphis, Tenn.

Smith joined Dixie Greyhound in 1931 as vice-president in charge of transportation and maintenance. He became president of the company in 1949.

Previous to serving with Dixie Greyhound, Smith was associated with the Fred Harvey Co., Kansas City, as assistant superintendent. He also worked with Smith Motor Coach Co. of Memphis as vice-president in charge of transportation and motive power.

DR. GUSTAV EGLOFF

Dr. Gustav Egloff, director of research for Universal Oil Products Co., died May 8. He had been a member of SAE since 1929.

Born in New York, Dr. Egloff received his A.B. from Cornell University in 1912, then went to Columbia to get his M.A. and Ph.D.

He immediately started to work with Universal Oil as a designer, specializing in motor fuels. He became director of research in 1934 and held that position until the time of his death.

Active in technical society work, Egloff held membership in the American Institute of Chemical Engineers, the American Institute of Mining and Metallurgical Engineers, American Chemical Society, Franklin Society, and the Institute of Petroleum of England.

EDWIN L. GRIFFIN

Edwin L. Griffin died March 9. He was president and general manager of Griffin Fuel Co., Tacoma, Wash.

He was born in Tacoma in 1908 and attended the University of Washington in Seattle. He later also attended Harvard University.

Immediately upon leaving Harvard in 1931, Griffin became president and general manager of Griffin Fuel Co. of Tacoma. He also served simultaneously as secretary of Griffin Fuel Co. of Seattle and partner of Griffin Brothers Coal & Oil Co.

ARTHUR B. SCHULTZ

Arthur B. Schultz, senior mechanical engineer, Argonne National Laboratory, Chicago, died of a heart attack May 1. He had been a member of SAE since 1930.

Schultz graduated from the University of Michigan in 1927 with a B.S.E. (Aeronautics.) He then joined Studebaker Corp. as junior engineer in the research department.

Since this first engineering experience, Schultz has held responsible engineering positions with such companies as Kermath Mfg. Corp., Ford Motor Co., Hise Aircraft Corp., Detroit Hydrostatic Brake Co., Pontiac Motor Car Co., Wilson Foundry Co., and Packard Motor Car Co.

He had become senior mechanical engineer at Argonne Laboratories in 1951.

JAMES DOUGLAS MORE GRAY

James D. M. Gray, aircraft production engineer, Air Service Floats, Ltd., Toronto, Ont., Canada, died recently.

He had been very active in technical organizations, holding membership in the Royal Aeronautical Society of England, the Institute of the Aeronautical Sciences, and the Institute of Metals in England.

His service as an engineer was felt in many fields, particularly among the Canadian military schools. However he also served as Flight Instructor and Flight Commander with the U. S. Air Force in Fort Worth, Texas.

The research field has felt his influence in the study of properties of heavy lead bronze bearings, the drag of towed objects, and the properties of proprietary glues, for instance. He has also obtained patents on improvements in aircraft controls.

Among the companies with whom Gray has been associated in various capacities are: Austin Motor Car Co., Ford of France, Inc., Handley-Page Aeroplane Co. of London, Otaco, Ltd., and Air Service Floats, Ltd.

REGINALD HILL

Reginald Hill, project engineer for Canadian Acme Screw & Gear Co., Ltd., Toronto, Ont., Canada, died in March.

Hill had been with Canadian Acme

Screw since 1951. Previously he had served with companies such as Turner Mfg. Co., Ltd., Guy Motors, Ltd., Imperial Chemical Industries, Ltd., and J. Tangyes, Ltd.

He attended Wolverhampton Technical College and taught motor vehicle science at the college in 1950-1951. His major engineering interest was diesel engine and tractor design.

A. VIRGINIA ROWLEY

Miss A. Virginia Rowley, standards engineer with Lockheed Aircraft Corp., was killed in a plane crash on April 25. She had been a member of SAE since 1946.

Graduated from Curtiss-Wright Technical Institute as an aeronautical engineer in 1942, she joined Lockheed the same year in the position of standards engineer.

Previous to attending Curtiss-Wright Tech, she studied liberal arts at Elmira College, Elmira, N. Y. and law at the University of Buffalo.

During these college years she served with Map Division of the Los Angeles County Assessor's Office as a map book checker, establishing property lines for assessment purposes.

ARTHUR G. PHELPS

Arthur G. Phelps, executive assistant to the general manager of Delco-Remy Division, GMC, died May 1.

Phelps, veteran of 43 years with the Division, was sales and service manager until his advancement to the office of executive assistant in September, 1954. He was widely known among automobile manufacturers through his long service as sales executive.

He was born in Chicago, Oct. 11, 1891. He attended schools in Butler, Pa., after which he began his business career in the production department of Dayton Engineering Laboratories Co., Dayton, Ohio, in 1912. When that firm merged with the former Remy Electric Co. in 1926, he moved to Anderson and was made service manager of Delco-Remy.

JOHN T. GALLATIN

John T. Gallatin, vice-president, consultant and director of advertising, Detroit Harvester Co., died April 1.

Born in 1904 in Lancaster, Pa., Gallatin attended the Franklin and Marshall Academy in Lancaster. He then went to Wesleyan University.

His business career started with the Budd Co., where he began as estimating and sales representative in 1928. From 1932 to 1937 he was contact man on several accounts for the company.

Since 1937, Gallatin has been associated with Detroit Harvester Co. There he has had considerable to do with the development and sales of the Hydraulic Window and Top Operating Mechanism used by automobile manufacturers.

from the

Sections

Baltimore

Field Editor H. T. Kline
May 26

A PRACTICAL DEMONSTRATION OF THE DEFENSE DEPARTMENT'S POLICY OF STRENGTH through standby production facilities was provided in a tour through the Chrysler Delaware Tank Plant. The M48 "General Patton" tank is now again in production.

The plant, built in 1951, was deactivated in early 1954 due to a contract termination. When Chrysler was awarded the new contract for M48 production later in 1954, it was necessary to reinstall all tools and obtain new subcontractors in many cases. It had taken slightly over four months to reactivate the plant, and the current M48 is being supplied to the Army at a lower price.

The tour covered the 1,250,000 sq ft of machining, assembly, and depot facilities of the plant and a ride over the test track. Two M48 tanks demonstrated the **maneuverability, gradeability, stability, and firepower** of this most modern medium tank.

Williamsport

Field Editor B. L. Sharon
June 6

BENEFITS ARE DERIVED BY ALL WHEN THE AIRLINES WORK TOGETHER WITHIN THE AIRCRAFT COMMITTEES OF OUR SOCIETY, stressed R. Dixon Speas, SAE Vice-President representing Air Transport Activity. Speas spoke briefly on this subject after extending greetings from SAE President C. G. A. Rosen.

This combined Golden Anniversary and Ladies Night program was an outstanding social success. The ladies were all presented with roses, dinner was served, and entertainment and dancing followed.

During the short business meeting, Ewing W. Mueseler, instructor at Williamsport Technical Institute, was installed as the new Section Chairman. 1954-1955 Chairman William Ribando was presented

a certificate of appreciation for his fine work in completing a very successful year.

Spokane-Intermountain

Field Editor T. H. Barker
May 13

FIVE OUTSTANDING PAPERS were presented by Student members at this Annual Student Activity Meeting. Prizes were awarded by the Section in the following order: First Prize, Richard Rhodes, Gozaga University—"What is Sacred About Oil Changes"; Second Prize, Roy Merrill, University of Idaho—"Cummins PT Fuel System"; Third Prize, Willis Laughton, Washington State College—"Overhead Camshaft Design"; Third Prize, Ken Mallett, Washington State College—"L.P. Gas for Internal Combustion Engines"; and Third Prize, Robert Feihl, University of Idaho—"Universal Position of Seat Tracks".

—Submitted by J. L. Peters

Southern California

Field Editor W. E. Achor
May 9

WE ARE VULNERABLE TO ATTACK BY A POTENTIAL ENEMY with the capability to inflict grievous, if not catastrophic damage upon our country, unless we are adequately protected. This thought lies behind the accounts given by Major General Frederic H. Smith, Vice Commander of the Continental Air Defense Command; Rear Admiral A. K. Morehouse; and Colonel Everett D. Light of the Army Anti-aircraft Command, who were speakers on the Civil Defense program.

The basic components of our defense system require an **early warning system, surveillance capability, and local defenses at our most vital targets**. We are engaged in a constant race to stay ahead of the enemy, which requires not only cooperation among the branches of the military, but also in the fields of industry, science, and government.

Discussion after the talks brought out that Canadian procedures are identical to ours; our own early warning system to the north is largely over the Canadian line.



ONE OF 33 BUSES which transported Detroit Section members from downtown Detroit and Ann Arbor arrives at the main gate of the Chrysler Proving Grounds, Chelsea, Mich. on May 7.



THE WATER BATH TEST, for ignition system water proofing and body sealing checks, was one of the points of interest along the tour route within the normally off-limits Proving Grounds.



JAMES C. ZEDER, 1950 SAE President and Chrysler Corp. vice-president, was principal speaker of the day.

Chrysler Proving Grounds Welcomes Detroit SAE Members

Details of Grounds operations provided by SAE Past President James C. Zeder, Chrysler vice-president



A CLOSE-UP UNDER-THE-HOOD APPRAISAL of the Chrysler experimental gas turbine engine is given by Detroit Section members including De Owen Nichols, Studebaker-Packard Corp. The engine was installed in a red and white 1955 Plymouth Belvedere four-door sedan.



DISTINGUISHED GUESTS AT THE SPEAKERS' TABLE included (left to right): Charles H. Chayne, vice-president, Engineering Staff, GMC; James C. Zeder, vice-president, Engineering, Chrysler Corp.; and Harry E. Chesebrough, chief body engineer, Chrysler Corp.

New England

Field Editor G. T. Brown
June 6

A FIELD SERVICE EQUIPMENT DISPLAY, MODERN CARS ON EXHIBIT, AND A GOLFER'S FIELD DAY were rolled into one at this annual summer outing held at Woodland Country Club, Newton, Mass.

The Army Corps from Fort Devens had a display of field service equipment from cranes to mobile repair shops. A helicopter display of amazing maneuverability was one of the highlights of the day.

An exhibit of the latest American and foreign cars including a Packard chassis with the new type suspension created a great deal of interest.

Glen Whitham was cited for his long and active association with New England Section.

San Diego

Field Editor M. E. Morrison, Jr.
March 8

THE SHOULDER-LOOP BELT IS NEARLY TWICE AS EFFECTIVE A RESTRAINING DEVICE as the lap-belt, according to crash injury tests made at the Institute of Transportation and Traffic Engineering of the University of California. Derwyn W. Severy, project engineer in Crash Injury Research at the University, told San Diego Section the story of the findings as reported in the paper "Automobile-Barrier Impacts, Series II."

Tests were made with automobiles occupied by two anthropometric dummies to facilitate evaluation of four conditions of motorist restraint: (in the order of increasing effectiveness) no restraint, lap-belt, chest-belt, and shoulder-loop belt. Test vehicles were steered by remote control into a fixed barrier at 25 mph. High-speed photography of the car and occupant during collision provided the basis for micromotion studies. Other tests suggest—that the shoulder-loop belt plus the lap-belt provides the most effective combination.

Detroit

Field Editor W. F. Sherman
May 7

CHRYSLER PROVING GROUNDS OPENED ITS DOORS TO SAE on Saturday, May 7, when 1200 members of Detroit Section invaded the premises. This new 4000-acre proving grounds near Chelsea, Mich. has never before been opened to tour by an outside organization.

James C. Zeder, 1950 SAE President and vice-president of Chrysler Corp., told the story of the development of the grounds in a talk entitled, "Importance of Proving Grounds Operations in Developing Modern Automobiles." He brought out the reasons behind the high-speed track capable of 140 mph on the curves without sidethrust, the gravel-

Alberta April 21



PRESENTING THE GAVEL to 1955-1956 Section Chairman C. H. Dawson (left center) is 1954-1955 Section Chairman Cyril Standen (right center).

San Diego March 8



HIGH SPEED PHOTOGRAPHY brings out the answers in crash injury tests at the University of California. Anthropometric dummies occupy the test car.

Section Meetings Schedule

Atlanta Section—September 12

Dinner 7:00 p.m. Meeting 8:15 p.m. "Where Do We Go From Here?"—Charles Froesch, vice president, engineering, Eastern Air Lines, New York, N. Y.

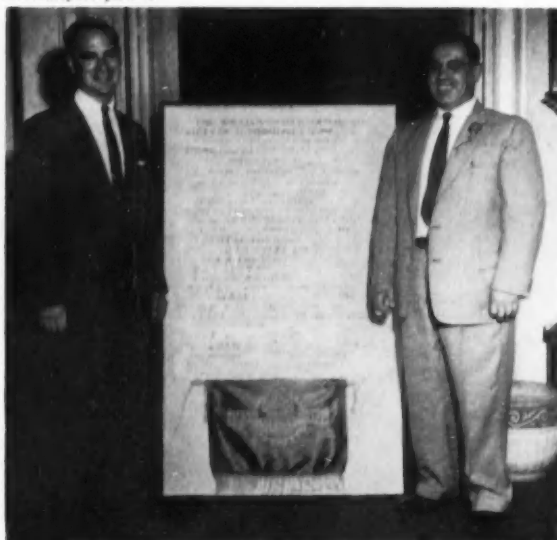
Hawaii Section—Aug. 23-24-25

August 23—Honolulu	1955 President C. G. A. Rosen—"The Influence of Alexander Botts on Automotive Design"
August 24—Maui	
August 25—Hilo	

surfaced contour endurance road with grades up to 20%, the 100 ft water bath, and the 45 deg "Burma Road Hill" where military vehicles are tested, for instance. And he noted that 3,000,000 miles a year are driven at the grounds to prove automobiles and trucks.

The firm off-limits rule for the Proving Grounds was relaxed for the SAE, he explained, because of the Society's clear technical and professional interest in such operations.

Williamsport June 6



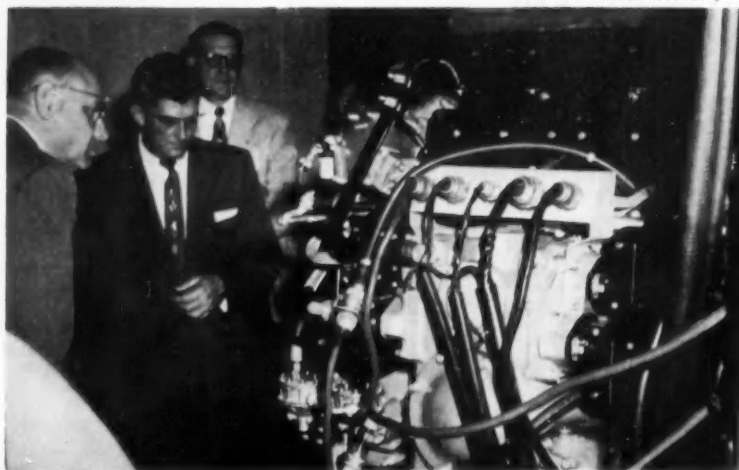
From Section Cameras

FEATURED SPEAKER at the combined Ladies Night and Golden Anniversary meeting was SAE Vice-President representing Air Transport Activity R. Dixon Speas (left). With him is shown 1954-1955 Section Chairman W. Ribando.

Baltimore May 26

ON TOUR OF CHRYSLER DELAWARE TANK PLANT, members examine the engine of the M48 tank in test cell. The M48 is the "General Patton" tank.

Baltimore May 26



MACHINING OPERATIONS on an M48 tank turret ring at Chrysler Delaware Tank Plant are witnessed by Baltimore Section members.

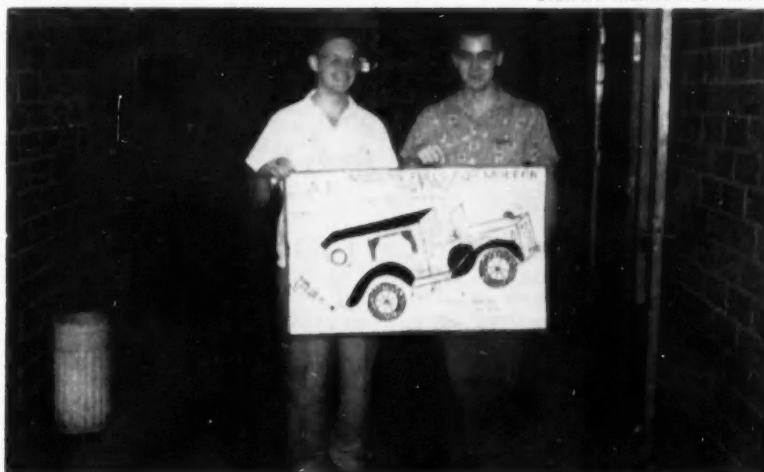


Student Cameras

MAC SHORT AWARD WINNER Robert Kreps (left), California State Polytechnic College, displays the Memorial award plaque with Cal Poly Student Branch Faculty Advisor J. O. Richardson. The prize-winning paper was entitled, "Heat Loss Through Oil Storage Tanks."

Southern Methodist University

HANDLING PUBLICITY for the "Modern Fuels for Modern Motors" meeting of SMU Student Branch were Harold Suder (left) and Weaver Lafferty. M. R. Morrow, Humble Oil and Refining Co., was the featured speaker.



University of Cincinnati



WINNERS OF THE FIRST ANNUAL ECONOMY RUN HELD May 14 are shown (left to right): Rolland McCullum; Allan D. Tilton; John H. Richter, Jr., proprietor of the Clifton and Howell Gulf Service, who furnished the prizes; Jack B. Hochadel; and Clarence Wuellner.



1954-1955 Branch Chairman Ed Heitzman (left) compliments the winning team of the Stevens Student Branch Road Rally. Pilot **Dick Shumway** holds the trophy as Navigator **Al Hill** accepts the Chairman's handclasp.

SAE in Action at

AN SAE Student Branch in action thrives at Stevens Institute of Technology. Under the capable leadership of Faculty Advisor Eugene Fezandie and Student Branch Chairman Edward Heitzman, 50 prospective engineers have joined ranks to put the machinery of SAE into operation as a stimulating force at Stevens Institute.

This 85-year-old engineering college was founded by Edwin A. Stevens, one of the three sons of Colonel John Stevens. His aim: to continue the flow of invention and constructive achievement that characterized his famous engineering family. Since the founding, a steady procession of men has come from Stevens to contribute to America's industrial leadership.

SAE Names from Stevens

Over 120 SAE members, who are active in the many phases of Society work, are representatives of Stevens Institute. These Stevens graduates, many of whom were Student Branch members while in school, are prominent engineers in their particular fields. Such names as Leigh K. Lydecker, Sr., Charles S. Mott, Ralph S. Lane, H. W. Roberts, Ralph H. Upson, and R. H. De Mott appear on that list.

Lydecker was president of Alox Corp. before retiring as a director of Maywood Chemical Works. His son, Leigh, Jr., service engineer with Babcock & Wilcox Co., joined SAE in 1954. Mott is a member of the board of directors of General Motors Corp. and has been since 1913. He is also the recipient of the Stevens Metropolitan Club Distinguished Service Award (See June Journal page 87.) Lane, now retired at Grosse Point Farms, Mich., was vice-president and treasurer of Equitable Trust Co. in Detroit. Roberts is president of Roberts Motor Co., Portland, Ore. Upson, one of the nation's authorities on lighter-than-air craft, is professor of aeronautical engineering at the University of Minnesota. Richard De Mott, chairman of the board and president of SKF Industries, Inc., was the 1954 recipient of the Stevens Honor Award.

The college differs from other engineering colleges by concentrating on a single, four-year course of engineering study. After completion of satisfactory work in this four-year course, the student is awarded the degree of Mechanical Engineer. He may then go on to get his Master of Science. Freshmen and sophomores take mathematics, physics, and chemistry in both years, together with additional subjects such

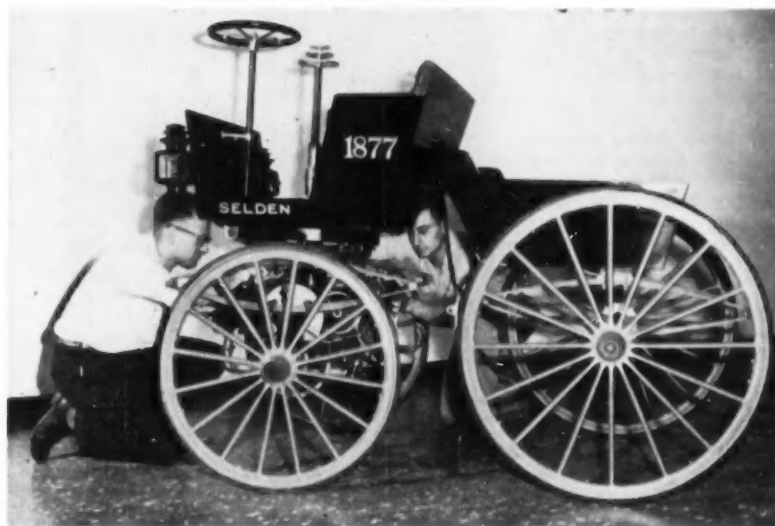
as descriptive geometry, materials, engineering drawing, mechanics, manufacturing processes, and mechanism. Juniors and seniors spend most of their time studying the engineering sciences and their application in chemical, civil, electrical, industrial, and mechanical engineering. Among the engineering sciences are fluid dynamics, thermodynamics, metallurgy, and machine design.

Located at Castle Point, Hoboken, N. J., on the Hudson River, Stevens Institute is within shouting distance of the cultural and career opportunities of the world's greatest city.

Stevens SAE Student Branch, founded in 1951, has built itself into a principal part of the extra-curricular activities available to the students. From the undergraduate student body of only 800, 50 meet once a month to share and gain experience. This membership has been recruited by the meeting programs and speakers, but even more by the activities sponsored by the Branch before and after these regular meetings.

The prime example during the 1954-1955 year was the road rally run by the Branch April 2. This was a contest to test driving skills and alertness

Chairman Heitzman (left) and fellow Branch member James Shashaty put the finishing touches on the 1877 Selden recently restored as a special project by the active Stevens Institute SAE Student Branch.



Stevens Institute

of drivers, and reliability of automobiles. The 54.6 mile route consisted of every type road imaginable from superhighways to a swamp running through someone's backyard. Faculty and student members worked together in this major operation.

But these outside-the-meeting activities at Stevens take many other forms as well. They constitute service for members and nonmembers. For example, bulletin boards have been set up in frequented areas carrying articles, announcements, and cartoons of general interest in the automotive field. The contents of these boards are changed once a week and have proved to be very popular with the students.

Information for Free

An information service which offers to answer "Any question about any automobile in the world, past, present, or future," has brought enthusiastic response. Student Branch Chairman Ed Heitzman says the group has not been stumped for an answer yet, despite a few trick questions. These questions range from advice on buying a new car to obscure information on the construction and performance of sports, racing, hot rod, and antique cars.

A library of SAE technical papers and complete collections of prominent automotive magazines has been set up by the Branch Library Committee. These collections of such magazines as **Motor Trend**, **Automobile Engineer**, and **Rod & Custom** contain as many as seven years' issues and the supply is continually increasing.

This aim toward service has been carried even further to include auto-

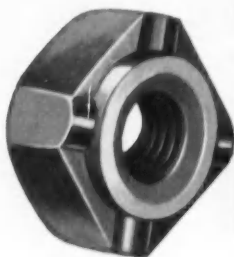
motive enthusiasts outside of the Institute. An 1877 Selden, recently restored by the Branch, is now on loan to an antique automobile museum. The car is the original model built as an exhibit in the celebrated legal battle between the Selden interests, who had been collecting royalties from

CONTINUED ON PAGE 94



As a service to members and nonmembers alike, Stevens Student Branch keeps the student body posted on available technical papers and magazines.

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SAE at Stevens Institute

continued

automobile owners for the use of their patents, and Henry Ford, who refused to pay. The date 1877 refers to the year in which George B. Selden claimed to have completed his designs, although a patent was not issued until 1895 and the court battle did not occur until the early 1900's.

The Society Reflected

SAE is reflected in its true light by these activities. The Society is characterized as a free sharing of knowledge, experience, and enjoyment. It reaches out in the form of service to nonmembers, ultimately enlisting their interest and cooperation. Here is Metropolitan Section reflected in its Student Branch at Stevens Institute.

Attendance of Stevens Branch members at Met Section programs and co-operation between Student Branch officers and Anderson Ashburn, Met Section vice-chairman for Student Activity, have served to enhance the full SAE story in both the Section and the Branch. Cooperation between the officers of Stevens Student Branch and those of the other Student Branches in the Met Section territory spreads the story further.

All Met Section meetings are open to members of the Student Branches. Programs of particular interest to these students are planned each year as special events in the Section calendar. Enthusiastic participation on the part of the Student Branches results in the major accomplishment of a feeling of unity. Occasional get-togethers of officers of the various Student Branches with Anderson Ashburn enhance this valuable feeling.

Providing material for publication in SAE Journal serves to expand the scope of interchange. Pictures of members in action plus news of special doings spotlight the strategic part the Student Branch plays in SAE. Additional publicity is available in Section meeting announcements and Section monthly publications, such as Met Section's **Accelerator**. The school has its publications open to Branch use. Students at Stevens Institute put out **The Stute**, a weekly newspaper. The Student Branch has provided frontpage stories for **The Stute** many times during the past year.

Taking advantage of these possibilities has helped to bring prosperity to Stevens Student Branch. But the real driving force has been the enthusiasm of its members. Much credit can be given to Chairman Ed Heitzman and Professor Eugene Fezandie for their part in lifting and holding this enthusiasm at its present height.

News About Special Publications

An Air Force general recently pointed out the urgent need for greater interchange of information on production methods and processes. Two up-to-date reports, just published by SAE, bring to manufacturing men the latest thinking in key automotive and aircraft industry plants.

- **SP-310**—Report of Production Forum of 1955 SAE National Production Meeting, highlights areas such as **chipless production** and **machine tools in automation**.
- **SP-311**—Report of SAE Aeronautic Production Forum, held last April in New York, touches on key problems in manufacturing modern aircraft and equipment for them. The "profitless prosperity" of the aviation industry picture today accents sections of this report, such as **getting maximum results from a cost reduction program** and **engineering changes in a competitive market**.

Each report grows out of the thinking of hundreds of production specialists. They're available to you for \$1.50 each if you're a member, \$3.00 if you're a nonmember.

* * * * *

THE SAE STORY is a fitting tribute to the men who 50 years ago had the vision to create the Society, as well as to the more than 20,000 members who today carry on in the traditions of the founding fathers.

This publication, which tells the story of SAE's first 50 years, gives an insight into motivations and the visions of the men who saw needs for technical interchange, and how they brought it into being. This new history of SAE suggests an even broader, more purposeful future of service to automotive engineering for the Society.

The **SAE STORY** is an easy-to-read, fast way of learning **what makes your Society tick and why it functions** as it does today. You can get a copy for \$2.00. (If you're not a member, it's \$4.00.)

Recent advances in car engines and automatic transmissions have refocused engineering attention on brakes. Just where we stand on the brake problem and where we're headed is pretty well crystallized in the newly available symposium "New Approaches to Solution of Passenger Car Brake Problems," SP-138.

This four paper symposium, which grew out of the SAE Golden Anniversary Passenger Car, Body, and Materials Engineering Meeting last March,

shows that modern car design is adding fuel to the heat dissipation problem. It also tells of progress being made in evaluating brake performance, brake materials and brake designs—particularly disc brakes.

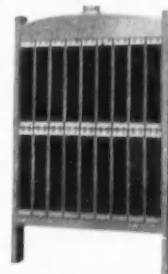
Here is today's brake story, fresh out of the labs and proving grounds of the men who are creating brakes for tomorrow's cars. It's yours for \$1.25 if you're an SAE member, \$2.50 if you're a nonmember.

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Air Traffic Control Allows for Transition

Based on paper by

G. F. QUINBY

National Aeronautical Corp.

THE so-called Common System of Air Traffic Control, which was documented at the request of Congress by an industry-government committee,

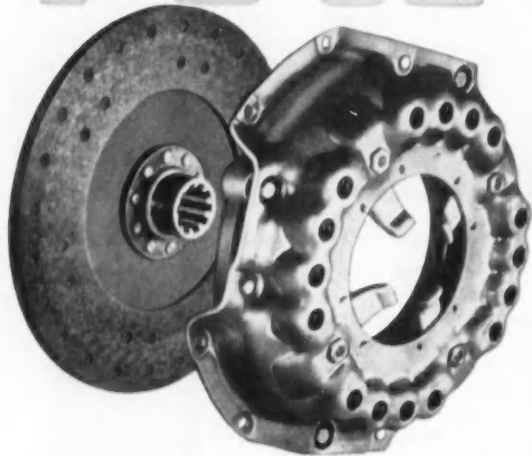
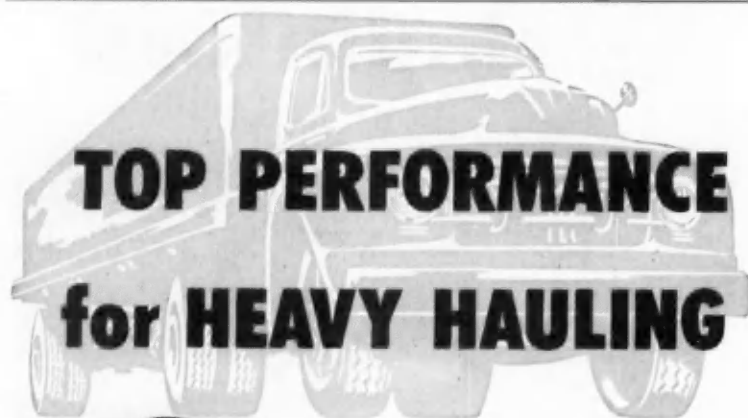
represents the fruit of much compromise.

The Common System detailed a transition from low frequency navigation and communication aids to the very high frequency aids with which we are familiar. Outstanding among the recommendations of the committee were the implementation of the visual omnidirectional range (VOR), the expansion of the instrument landing system (ILS), and the establishment of radar ground controlled approach (GCA) as a secondary terminal aid

complementing the ILS. VHF communications were standardized and Distance Measurement Equipment was put on the program for the earliest possible implementation.

The committee programmed new aids in two phases. What we use today all came under the heading of an interim or transition control system. As such, they were a compromise between what the planners knew would be required eventually and what they knew could be implemented within the state of the electronics art at the time of their report. So, they put down a second set of specifications showing the operation requirements of an "Ultimate" system of control. This Ultimate System implied a later transition where technical developments permitted and traffic requirements warranted more system performance than would be available with the interim system.

(Paper "Radio Communication and Navigation Equipment for Utility Aircraft" was presented at SAE Wichita Section, Nov. 12, 1954. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to non-members.)



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Flame-Plating Solves Many Wear Problems

Based on presentation by

G. B. RAY

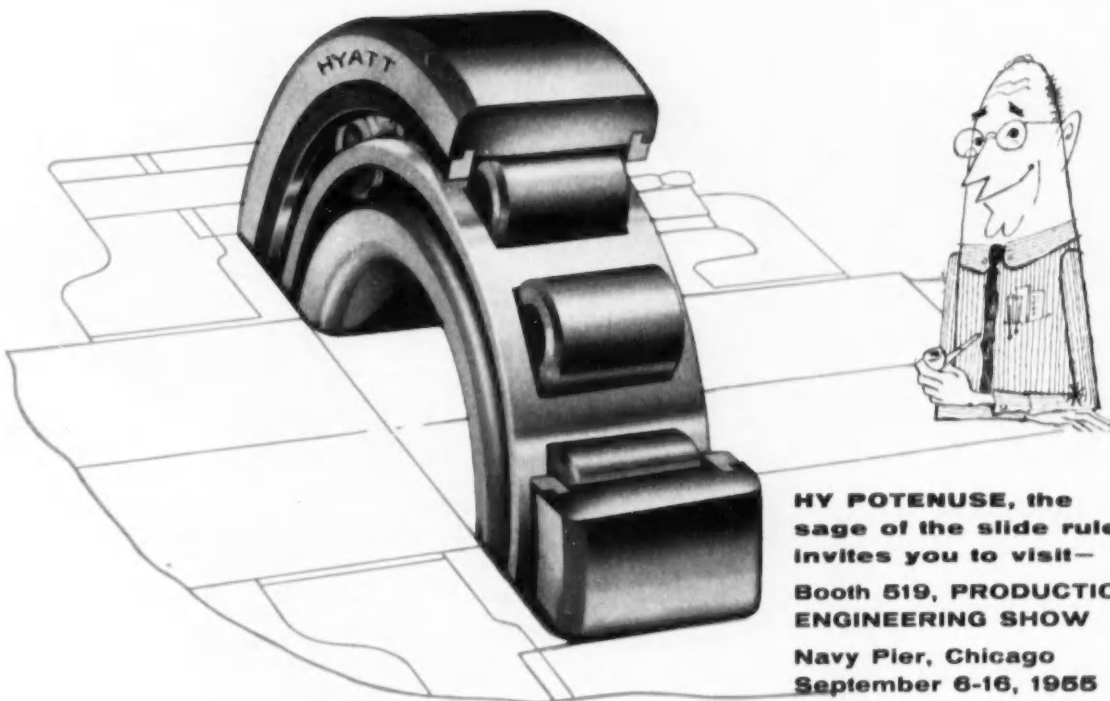
Linde Air Products Co.

FLAME-Plating is a method of applying coatings of tungsten carbide to metal parts. The deposit is made in the form of a hard, wear-resistant coating that can be applied in thicknesses ranging from 0.002 to 0.010 in. Extensive tests show that Flame-Plated coatings are unmatched for a wide variety of applications in their resistance to frictional and abrasive wear and fretting corrosion.

In Flame-Plating an excellent interlocking bond between coating and base metal is obtained with no voids or interruptions whatever. The bond is more than mechanical. The process induces a surface welding reaction that, though only microscopic in depth, gives an extremely tenacious bond.

One of the major advantages of this new process is that the temperature of the base piece does not usually exceed 400 F during the plating operation—even when metals with extremely high melting points, such as tungsten carbide, are being deposited. This eliminates practically any possibility of a change in the physical properties of the base metal, and reduces to a minimum the chance of distortion. For

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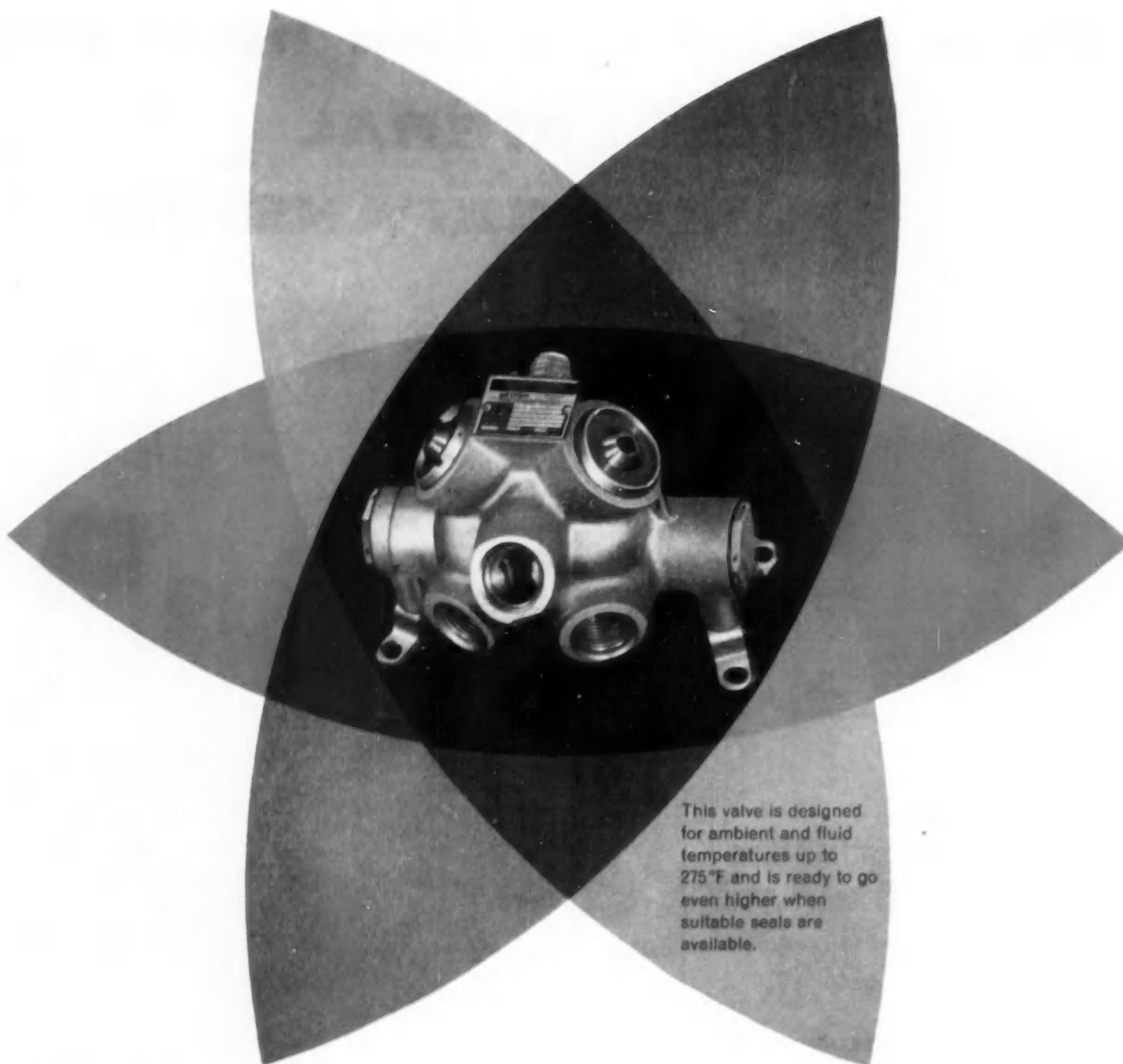
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this reason, the process is well-suited for use on finished or semi-finished precision parts where physical properties have been predetermined.

Several coating materials have been tested for use with Flame-Plating. However, for the present, commercial application is confined to tungsten carbide. The coating material used is composed of tungsten, carbon, and 8% cobalt. These elements are present in a form differing from sintered tungsten carbide.

Tungsten carbide can be deposited on almost any base metal by Flame-Plating. Steels of all types, cast iron, aluminum, copper, brass, bronze, titanium, and magnesium have all been coated successfully by this new process. At the present time chromium plating and all forms of tungsten carbide alloys cannot be satisfactorily coated with tungsten carbide. Flame-Plated parts, however, may be re-coated if the original coating is completely removed.

The wide selection of base metals that can be Flame-Plated has made this process specially attractive to the design engineer. For example, the combination of light weight, low moment of inertia, and high wear resistance can be obtained by Flame-Plating aluminum, magnesium, or titanium, with tungsten carbide. The design engineer can use the toughness of steel or the easy machinability of brass and at the same time take advantage of the extreme wear-resistance qualities of tungsten carbide through Flame-Plating. Thus, many problems can now be solved by using the desirable properties of a base metal with tungsten carbide to obtain a superior combination.

Flame-Plating is already being used on plug gages, turbine engine seals, cold-forming dies, bearings, and many other items.

Presentation was made at SAE Northwest Section, Dec. 19, 1954. Presentation and above abridgment were based on brochure "Flame Plating" available from Linde Air Products Co.)

X-Rays Measure Residual Stresses

Excerpts from paper by

J. A. HALGREN, T. C. HUANG,
and E. I. BLOUNT

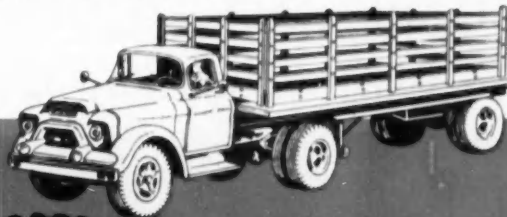
International Harvester Co.

BASICALLY, the x-ray diffraction method of measuring residual stresses is a strain gage method. It uses the specimen itself as a gage.

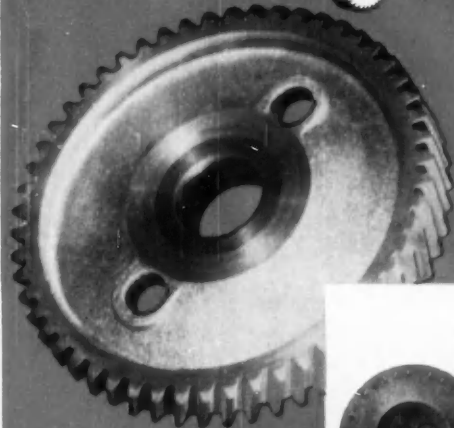
When x-rays of relatively long wavelength, of the order of one Angstrom unit (10^{-8} cm), strike a crystalline material, some of them are deflected from their course. Each atom in the crystal is set into vibration and then acts like a transmitting antenna.

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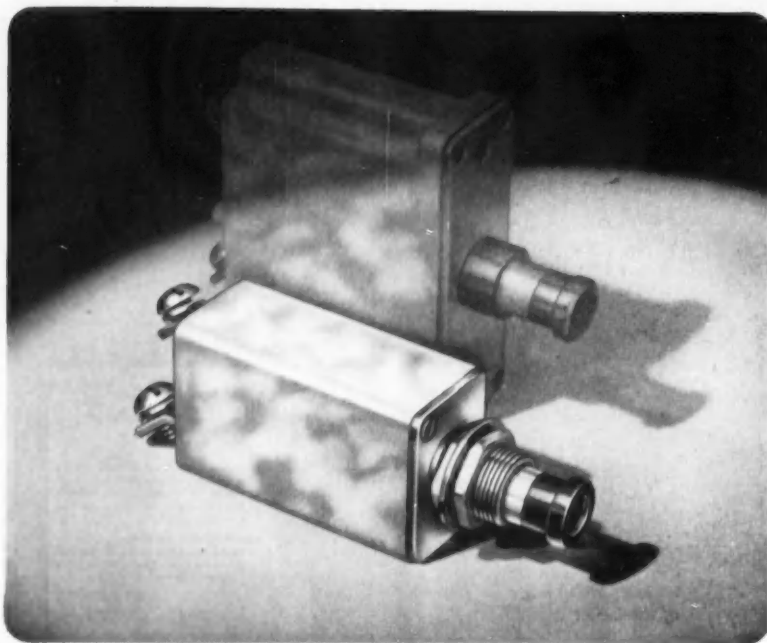
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distance of the order of a wavelength, they behave like a directional array of antennas, sending x-rays out only in a few specified directions. These directions depend upon the pattern and size of the lattice on which the atoms are placed.

If we imagine that the specimen is at the center of a globe, with the incident beam coming in from the north along the axis, scattered x-rays may emerge at certain definite latitudes. If the specimen contained a great number of crystals with all orientations, there would be scattering to all these special latitudes but averaged out randomly to all longitudes. That is, there would be rings around the globe at certain latitudes. These latitudes depend on the distance between the atoms. These distances depend on the stress in the specimen.

Therefore, in theory, by measuring the latitudes at which we get diffracted rays, we can determine the stress. The particular equations which must be used can be found in the literature.

This method has been widely applied to nonferrous metals and to annealed steel with generally satisfactory results. In the last few years there has been considerable work done on its application to hardened steel, but there is considerable disagreement on the success of this work to date.

The reasons for this difficulty lie in the fact that hardened steel has a much less perfect crystal structure and higher yield strength than most of the other materials tested. Its high yield strength means that there can be much greater variations in stress from one grain to another. This has the effect both of spreading the diffraction out over a wide range of latitudes and of raising doubts as to just what stress is being measured. (Only a small group of grains with a special range of orientation contributes to the diffraction at each latitude, so that the average stress measured for these grains may differ considerably from that for the whole specimen.) The imperfection of the crystal structure has the effect of further spreading the diffraction lines, essentially as a directional array of antennas might lose its directionality if the antennas were displaced from their proper position.

There are ways of dealing with these problems and getting an answer. In particular, the method can be used quite reliably for the measurement of applied stresses, or the difference between two stresses in the same specimen. It is in the establishment of a base that the difficulty arises.

The x-ray method is a nondestructive method, if only surface stresses are determined. In order to find subsurface stresses, material must be removed, just as in mechanical methods.

It is possible to use x-rays on areas much smaller than are required for electrical resistance strain gages. On the other hand, the shape of the specimen must leave a path for the incident and diffracted beams to and from the area of interest. It is a rapid method, by and large, requiring less than an hour for nonferrous metals

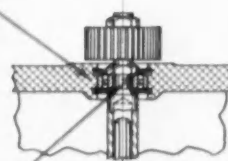
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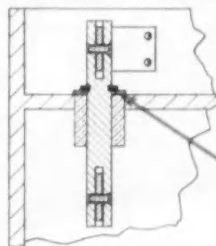


Drive Spindle Assembly



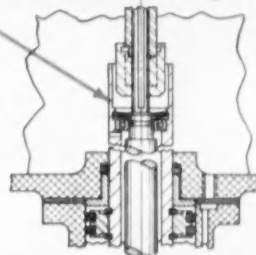
Bearing is held in position by two Waldes Truarc Rings—Standard (Series 5000) and Bowed (Series 5001). Two grooves are turned and housing rough bored in one operation. Alternate method would require at least two additional machining operations. Bowed Truarc ring takes up accumulated tolerances resiliently.

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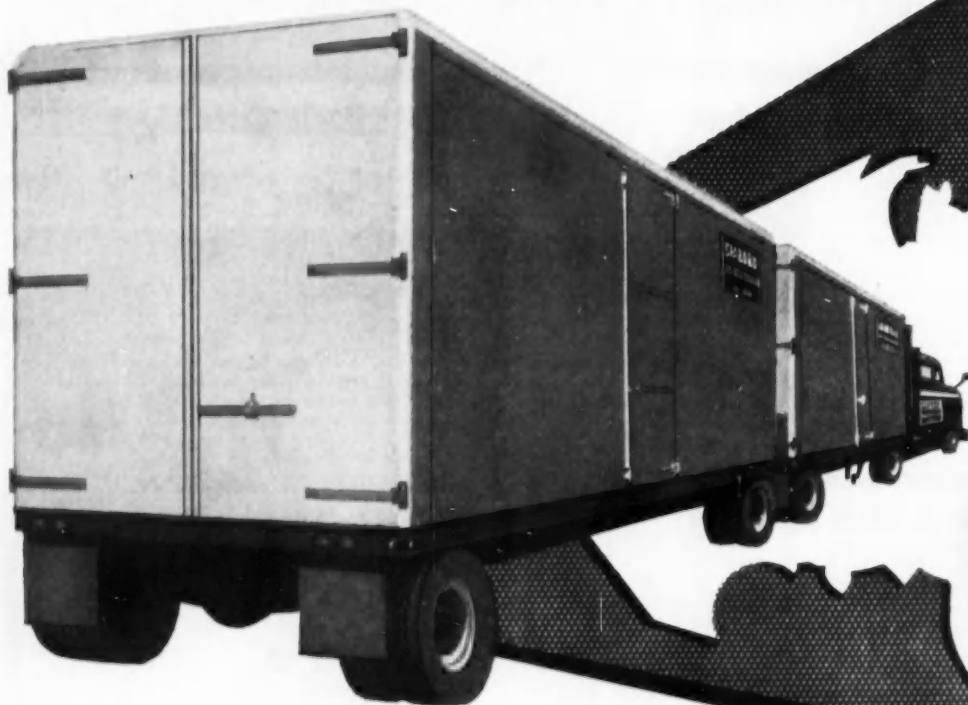
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and from 2 to 10 hr for hardened steel, depending on the method used and the area exposed. The method has been widely used in the more than 30 years since it was first devised.

Complete paper from which this excerpt is taken reviews the literature on mechanical and chemical, as well as physical, methods of measuring residual stresses. The paper is available in full in multilith form from SAE Special Publications Department at 35¢ to members, 60¢ to nonmembers.

Discussion

A. L. Christenson,

Timken Roller Bearing Co.

The measurement of stress by x-rays is, as in all other techniques, a measurement of strain, which measurements of strain are then arithmetically converted to values of stress on the assumption of certain theoretically derived relations on the basis of a calibration procedure. Therefore, to evaluate the practical usefulness of this method of stress determination, two questions are posed. First, how sensitive and reproducible are the measurements of strain in terms of stress? And second, are the stress values computed from these strain measurements the same as those ordinarily obtained from other techniques such as the Sachs boring-out method?

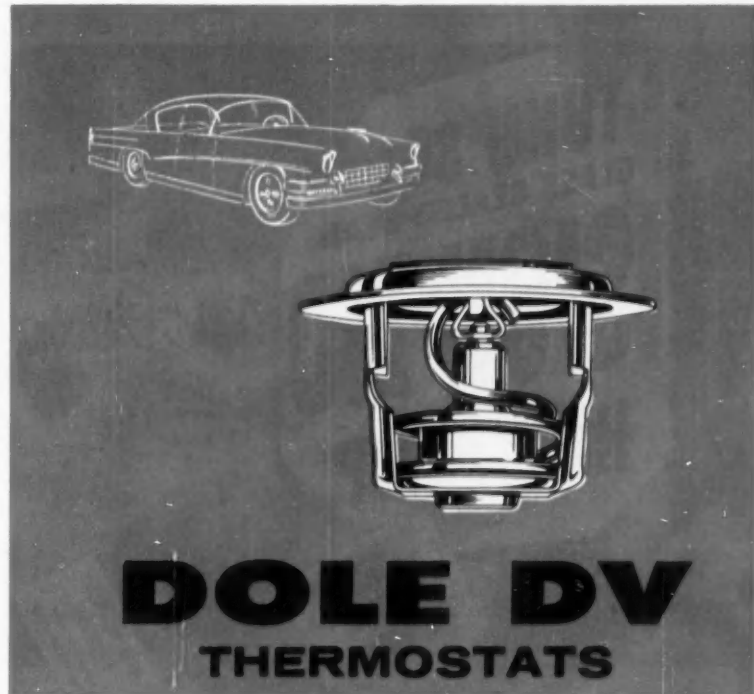
The measurement of strain by x-rays is obtained merely by observing the change in the angle of diffraction of a particular diffraction line when the angle of incidence of the x-ray beam to the sample surface is changed. This, in principle, is quite simple, but implies an elegance to the procedure that is not perhaps deserved, because we note that the diffraction lines obtained at high hardness levels are broad, possess ill-defined peaks, and do not lend themselves to precise positioning. Thus, when we consider that a very high level of stress will produce an angular shift in the line that is small compared to the angular width of the line, the practical difficulties are manifest. For example, an angular displacement of only 1 deg. 20' amounts to roughly 60,000 psi when the angle of incidence is changed 60 deg.

With respect to this difficulty, there is, on the other hand, a saving feature. In the strain measurement it is only necessary to determine the angular 2θ shift in the line and not the absolute position at any one angle of incidence. Hence, we may assign a relative position to the line by extrapolating the line sides to their peaks or by the least-square fitting of a symmetrical curve to the peak of the line. In this connection, however, one more factor must yet be considered. When the angle of incidence of the x-ray beam is changed, a change in line symmetry is observed, resulting from a different condition of

x-ray beam absorption within the sample—a change in symmetry which may reflect in a false indication of the relative line position. The solution to this problem is not so readily apparent, but for the purpose of this discussion it will suffice to know that means are available for compensating for the change in absorption, and consequently, we have a procedure which, though now being far from aesthetically satisfying, is rigorous and adequate to answer our first question posed. Checking this

procedure against strain gages mounted on elastically bent specimens established a routine level of reproducibility of strain measurement by the x-ray method equivalent to ±3000 or 4000 psi.

The second question raised at the outset of this discussion is one more commonly discussed in text material on the subject and is considerably more subtle. The reason for this is that the relation between strain and stress is a function of the elastic constants for



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the material; namely, the modulus of elasticity and Poisson's ratio. Unfortunately, these constants vary with direction within a single crystal of iron since iron is anisotropic—a fact which is of no consequence in mechanical techniques for stress measurement in the absence of serious preferred orientation because the measurements are made on the mass as a whole, and an average or bulk value for each of these constants obtain.

In the measurement of strain by x-rays, the measurements are made

only on crystals within the mass that are aligned at a certain direction to the direction of stress. Therefore, we are confronted with the possibility that the strain or stress we measure bears little relation to the average strain or stress present in the mass as a whole. Furthermore, the fact that different yield strengths are expected at different directions within the crystal and each crystal is constrained within the mass in an unknown manner, has prevented any satisfactory mathematical treatment of this prob-

lem. Thus, it is necessary to resort to experiment to ascertain the seriousness of this situation.

By comparing the x-ray measurements of strain obtained within the crystals of tempered martensite against the strain gage indications of the movement of the mass sample, it is possible to compute the elastic constants appropriate to the individual crystallites in which the x-ray strain is measured. Much to our surprise, when this was first done, a few years ago, the elastic constants for the individual crystallites measured proved equal to the elastic constants for the mass of the sample. The question immediately arose then and still persists somewhat in our minds today, "Is this the fortuitous result of the particular diffraction line chosen and, hence, crystallite direction measured, or is the apparent conformity of the elastic movement of the individual grains to the movement of the mass a fundamental property of the metallographic structure of hardened, high carbon steel?" I would like to suggest for your consideration that the latter is more likely true.

Assuming for the moment that each crystallite comprising the mass has different elastic properties in different directions and then visualizing that each crystal is confined among other crystals at all random orientations, it is obvious that at the points of impingement, a disorganized relation of stress and strain will exist and persist to at least some distance into the crystal interiors away from the crystal junctures. Now, if we conceive that the thickness of the individual crystals is of the same order of magnitude as the depth of disorganization, in principle we have arrived at a mass of anisotropic crystals which behave when confined in the mass in an isotropic manner. I believe the thinness of the martensitic needles is to a large extent responsible for the aforementioned results.

It having been established from the calibration procedure and elastic constant studies that stress differences could be measured adequately, the question of whether the stress measurements were accurate on an absolute basis and comparable with other techniques yet remained, because it is evident that hard steel samples with known stresses need to be measured, and these until the last year or so, have not been obtainable.

Meanwhile, many measurements were made on thin martempered samples in which one would intuitively expect the magnitude of the macro-stress level to be low, and on through-hardened and on carburized specimens in which the direction of stress (tensile or compressive) could be intuitively forecast—all of which suggested the stress measurements to be reasonably accurate. (However, recently a specimen was received from the Mellon Institute which, on the basis of the newly developed Letner dissection tech-

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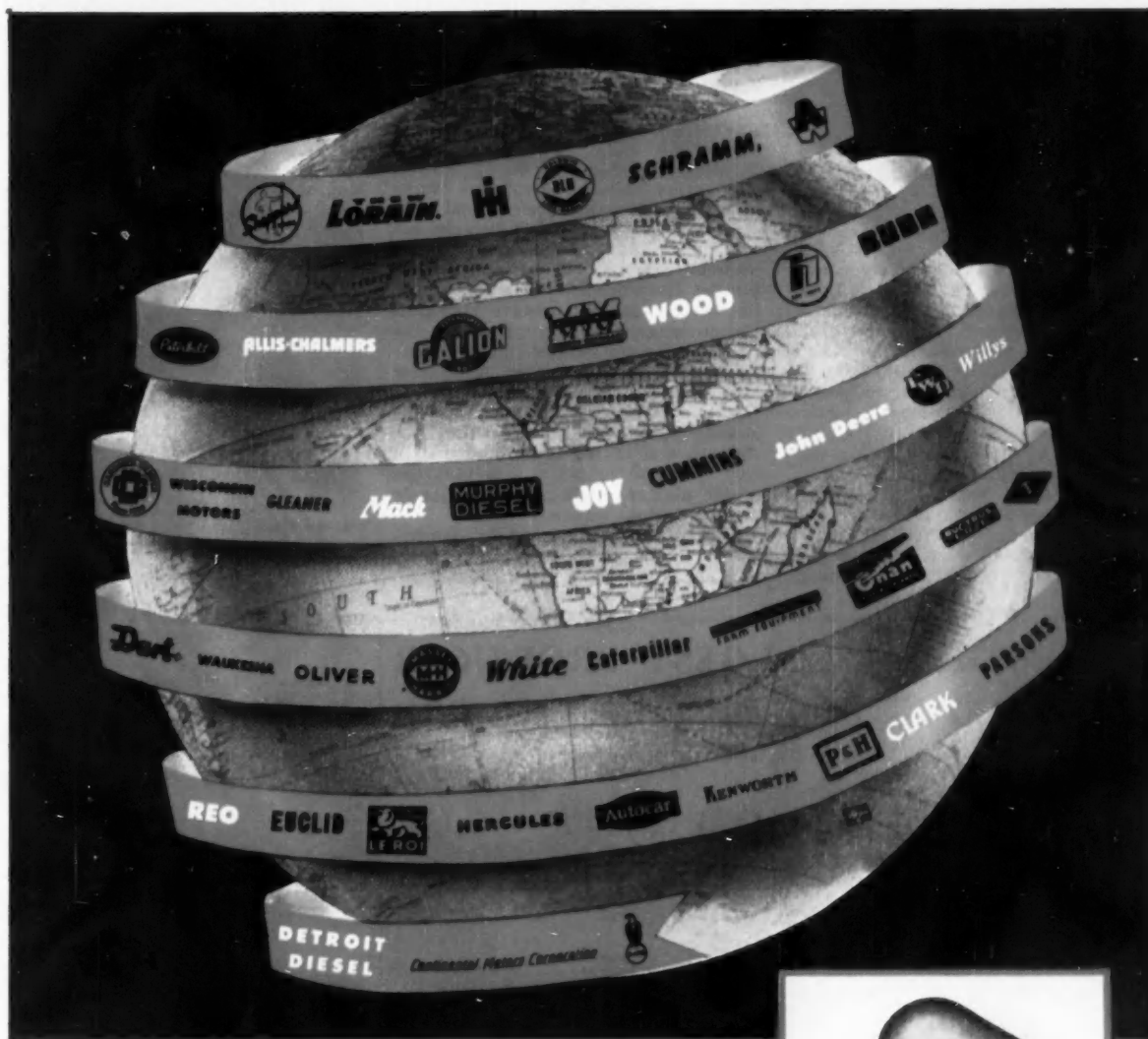
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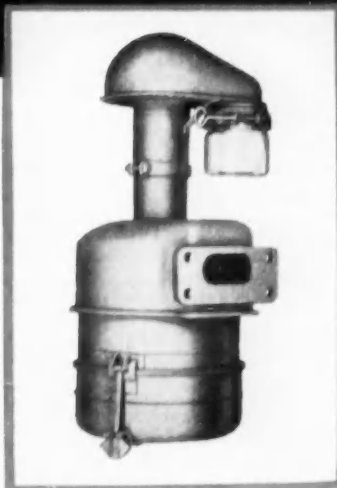
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nique, indicated surface stress levels of +590 and +430 psi, respectively, in the longitudinal and transverse directions. Our measurements indicated +1400 and -360 psi in these two directions.)

The excellent agreement between the two techniques we feel justifies acceptance of the x-ray approach to residual stress measurements in hardened high carbon steels, which have not undergone appreciable cold deformation, along with the more commonly used mechanical methods.

R. L. Mattson,

Research Laboratories Division, FMC

Perhaps the most important contribution that anyone could make in the field of residual stress study would be to provide us with a practical and preferably non-destructive residual stress measurement method, be it x-ray, magnetic, electrical resistance, mechanical, or other means. Along this line, we have been particularly interested in indentation testing such as is done in measuring hardness.

In one experiment, we measured the topography of indentations which were made in a piece of SAE 4063 steel hardened to Rockwell C 59 while it was stressed to varying amounts in bend-

ing. The surface was prepared by grinding and polishing. The indentations were made with a 1/16-in. diameter tungsten carbide ball using a load of 30 kg. The size and shape of the resulting indentations were studied with an interference microscope.

In the upper part of Fig. A are the resulting optical interferograms. These are essentially topographic maps. By counting the number of lines, one can determine the depth of each of these indentations. The differences are quite startling.

Fig. B presents the results a little more graphically. The top line represents the surface and the vertical scale downwards represents the distance below the surface. The distance from the vertical axis of the indentation is plotted horizontally. The top curve, for 180,000 psi compressive stress, is the cross-sectional contour of the indentation made under those conditions. You will note that it is quite shallow. The deepest curve shows the results obtained for 180,000 psi tensile stress. It will be observed that the difference is of the order of three to one. It is to be noted also that the crater diameter differed only slightly for the various stresses.

This experiment serves to demonstrate that the elastic recovery and hence, the amount of plastic flow which

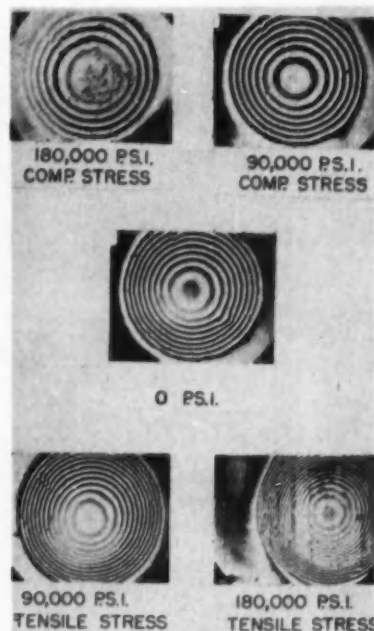


Fig. A—Photographs taken through an interference microscope show marked differences in ring patterns around indentations made by a 1/16-in. diameter, 30-kg tungsten carbide ball. Specimens were stressed before indenter struck. Number of rings varies with degree of prestressing.

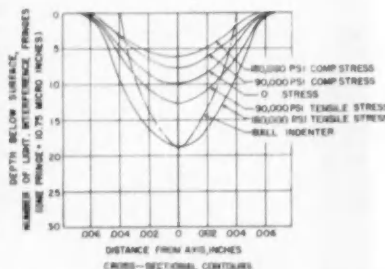


Fig. B—Depth below surface, as indicated by interference fringes, of indentations made in a piece of steel stressed to various degrees. The greater the compressive stress, the more shallow the indentation. The greater the tensile stress, the deeper the indentation.

occurs under such load conditions depends upon the stress state. This is perhaps not surprising, but a most interesting point is that the order of magnitude is so great. Here, of course, we have shown only the influence of the change of stress in that no zero stress condition was known.

Complete load versus depth measurements could be made during the entire loading and unloading cycle of making the indentation. This would seem to me to be a logical step forward in the evolution of the indentation hardness measurement. It would appear that much more knowledge of engineering materials might be obtainable if pre-

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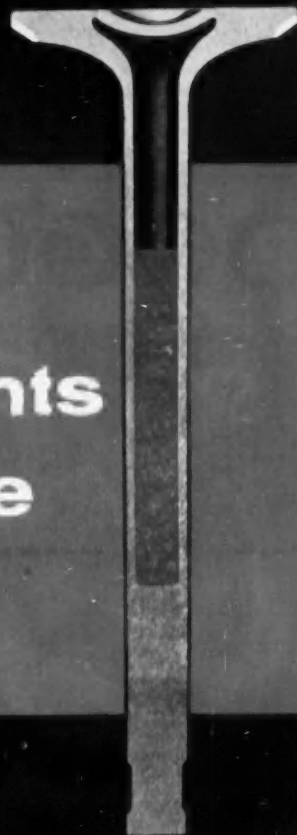
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cision indentation tests were made in which stress state, basic hardness or yield strength, and work hardening characteristics could be studied and perhaps resolved.

Author's Reply

I would like to point out particularly that the pioneer work done at Timken on the development of the x-ray diffraction technique is proving very helpful to all people using this method. It is apparent that residual stress results

are becoming more reliable with progressive refinements in technique so that it is possible to interchange results obtained from many laboratories with confidence in the reliability of those figures. It is also evident, however, that much work remains to be done in the development of measuring methods.

Continuing developments in residual stress measurements indicate the probability that many errors are present in the older literature on this subject. For one thing, much early work was done on ground specimens with little recognition of the presence of very

high stresses on a thin layer of surface material. For these reasons, it is well to consider carefully any application of the early literature.

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Based on report by

W. F. MELHORN

Tube-Turns Division, National Cylinder Gas Co.

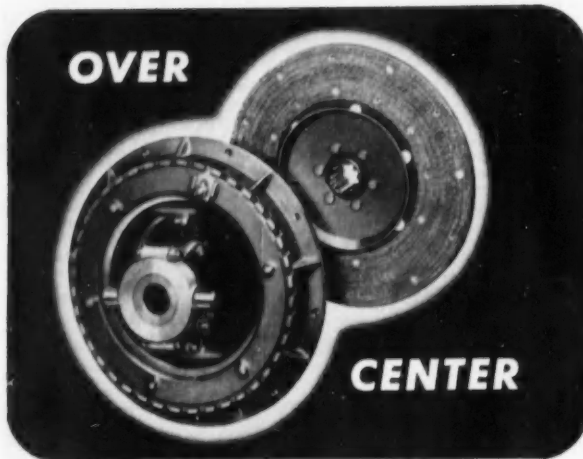
LEADED STEELS have been heat-treated without unusual difficulties, but the practice seems not to be widespread. One concern, having made a dozen different cost studies on leaded steels, finds savings insufficient to justify switching over to them. And, in addition, suppliers would not guarantee that they could be carburized in the same manner as unleaded steels.

Machinability of leaded steels is superior to that of the unleaded, but the extent of the improvement is in question. One company declares machinability improved 100%, but since carburizing grades were not used, there was no problem of heat-treating. Three other users maintain the maximum gain to be no more than 10 to 25%.

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Panel Secretary

W. F. Melhorn,

Tube-Turns Division, National Cylinder Gas Co.

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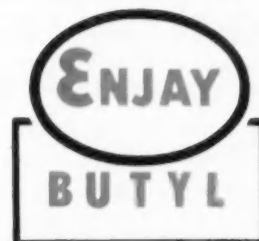
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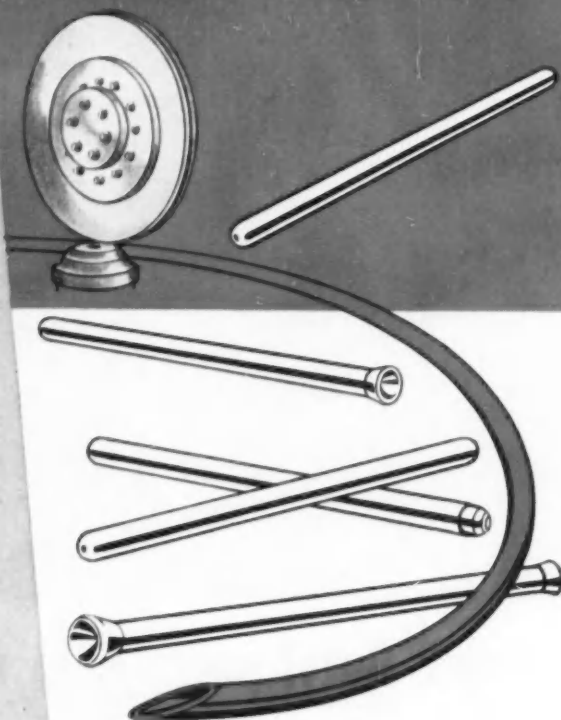


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ity, would the speed-ups be allowed? There is evidence, in answer to this question, that many companies would not dare to introduce such an increase in production without first re-designing the part to the point of being unrecognizable.

(This article is based on the secretary's report of Panel on Selection of Materials As It Affects Production Costs held as part of SAE Golden Anniversary Production Meeting and Forum, Cincinnati, March 14, 1955. It is available in full in multilith form together with the reports of the other seven panels as SP-310 from SAE Special Publications Department. Price: \$1.50 to members, \$3.00 to nonmembers.)

Galvanic Corrosion Becoming Airframe Woe

Based on paper by

C. W. ALESCH

Convair Division, General Dynamics Corp.

NOW that a variety of materials is available, airframes of the future will most likely be composites of different materials, each chosen to fulfill a specific function. And as the use of temperature resisting materials grows, the problem of galvanic corrosion will increase.

By definition, galvanic corrosion is the accelerated electrochemical corrosion produced when one metal is in electrical contact with another more noble metal, both being in the same corroding medium. Such corrosion usually results in a higher rate of solution of the less noble metal and protection of the more noble.

This means that magnesium and aluminum alloys will, when in contact with stainless steel, titanium and the like, in the presence of moisture, be sacrificed to protect the heavy metals. It also means that with wider use of stainless steels and titanium, effective areas of these cathodic metals will increase and, as a result, corrosive damage will manifest itself in aluminum and magnesium alloys early and in serious amount because of greater currents developed. Further, with riveting, welding, and similar joining methods, metal-to-metal contacts will be good and, certainly in marine atmospheres and very possibly in inland atmospheres, electrolytic contacts will favor closed corrosion circuits.

Cathodic polarization, commonly evidenced by accumulation of hydrogen at cathodes, has been shown to be effective in reducing corrosion potentials to zero and halting corrosive action. Hydrogen, however, being lighter than air is somewhat difficult to retain on

the desired areas. This phenomenon suggests strongly that artificial polarizers, paints, insulating strips, and so forth, will effectively minimize corrosive action if judiciously applied to cathode materials such as stainless steel and titanium.

The work of Evans and others indicates that anodic corrosion occurs through the release of metal ions into the surrounding electrolyte where they react to form metallic hydroxides. These deposit on anodic surfaces to

form corrosion-product mixtures of hydroxides, oxides, and electrolytic salts. Under favorable circumstances the deposits serve as depolarizers which do have a certain retardant value but are not reliable for protective measures because of their physical nature and method of attachment.

It appears from the foregoing that to ease the task of building and maintaining aircraft which are to undergo elevated temperature service, much can be done in designing integral com-

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Stud Damage Reduced

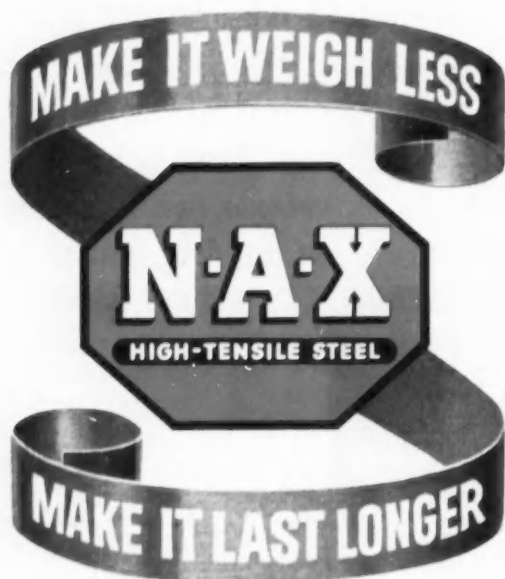
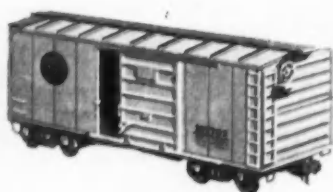
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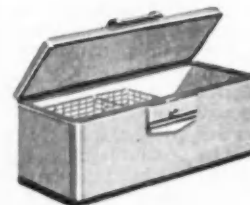
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ponents entirely of either anodic or cathodic metals, applying appropriate protective measures to detail parts, and then applying corrosion retardant steps at assembly joints. In view of the many temperature problems prevalent with paints and similar nonmetallics, design simplification plays a significant part in further use of temperature resistant materials.

(Paper "Some Trends in Elevated Temperature Airframe Materials" was presented at SAE Aircraft Research Seminar, University of California, Los Angeles, Dec. 8, 1954. It is available as SP-128, together with eleven others from SAE Special Publications Department. Price: \$3.50 to members, \$7.00 to nonmembers.)

Aviation in 1980 Will Look Like This

Based on paper by

VAL CRONSTEDT

A. V. Roe, Canada, Ltd

BY 1980 all people and all goods with a few special exceptions such as commuters and low grade freight in the mineral category will be carried by airplanes and helicopters the world over. None will be carried in ships' bottoms, by rail, or by road.

Transport airplanes of 500 tons or larger will be commonplace. This may seem small in comparison with ocean liners of 50,000 tons, but such a transport will make 20 trans-Atlantic crossings in a month while the S.S. United States, the fastest of them all, will make two. And there will be at least an 80% saving in pipeline dollars.

Global transports will fall into two main categories. One, the fast one, with gross weight of 450 to 500 tons, will cruise at slightly below sonic speed for ranges of 3500 to 4000 nautical miles. Its main objective will be the transportation of people, and high grade cargo which it would be criminally uneconomical to hide in "pipelines." The slower airplanes for freight will have a gross weight of 500 to 550 tons and fly at 500 to 600 mph. Their range, decided by global geography, will also be 3500 to 4000 nautical miles. This will be a really fat, bulky airplane since at prevailing cargo weights per cubic foot the space required for useful load will be as big as a house.

The cruising speed just mentioned seems to indicate a rather modest increase over those prevalent and spoken of today. The transonic drag is, however, a real obstacle that will defy elimination and the power demand to penetrate it is to me an economic absurdity. Until shown differently, I will stick to these predictions.

The cruising altitudes that will be selected for these aircraft in all likelihood will be on the order of 50,000 ft.



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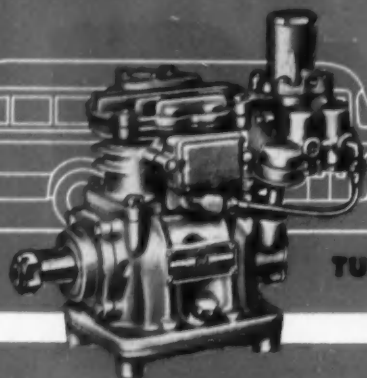
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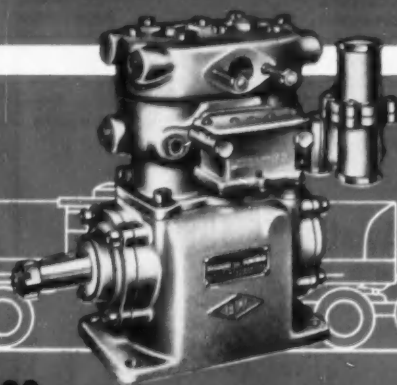
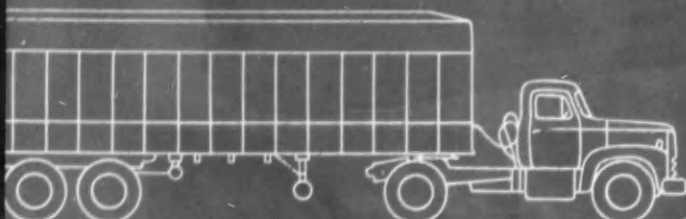
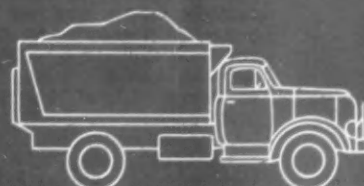
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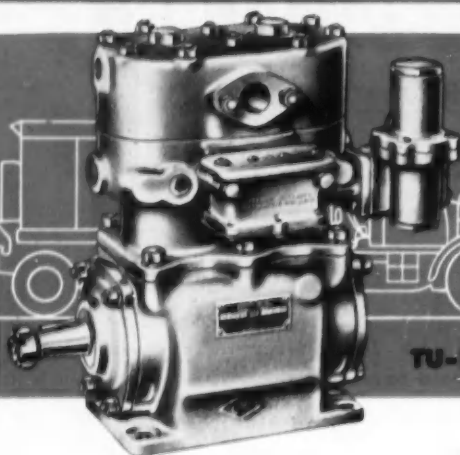
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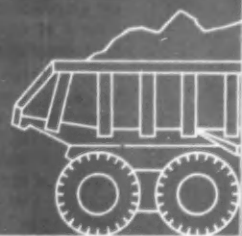
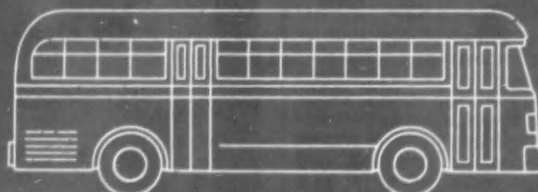
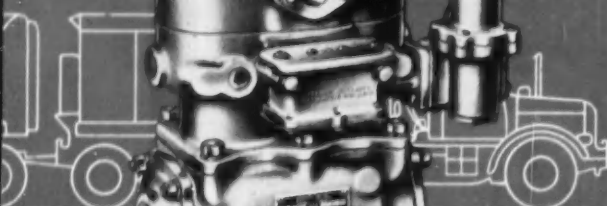
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Add to this lower discharge temperatures and superior oil control and you can see that TU-FLO Compressors positively assure more road-time, less shop-time. Make sure your trucks or buses are Bendix-Westinghouse TU-FLO equipped. They're available in three models to fit every size vehicle from the smallest to the largest!

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The powerplants will be limited to four in number. To think of more is unrealistic.

The fast class will be jet propelled with engines of about 50,000-lb sea level static thrust or more. Devices for assisted take-off will be tolerated for certain military transport operations, but I seriously doubt that the travelling public will endure the racket associated with being pushed off the ground with a rocket, even in sophisticated A.D. 1980. If present economics of the matter prevail, the freighter will be equipped with 25,000 to 35,000 shaft hp propeller turbines.

There will be large passenger-carrying helicopters replacing the successors to the Convair 240 and 340 and the Viscounts. There will also be large freighter helicopters replacing the trailer trucks now cluttering the highways. Then there will be assorted sizes used by firms for transport of their officials, service men, and travelling salesmen.

As for personal flying—the Piper Cub replacing the private automobile—I see even less hope than I did 25 years ago. The restraining and precise controls needed for the dense three-dimensional traffic of 1980 will be so irksome that the family spin to the picnic grounds will still be made in dad's car, and with no trucks on the road it will be a pleasure.

(Paper "The Next Twenty-Five Years in the Aviation Industry" was presented at SAE Williamsport (Pa.) Section, April 4, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Bypass Turbojet Is Worth Developing

Based on paper by

GEORGE F. WISLICENUS

The Pennsylvania State University

THE bypass turbojet or ducted-fan type of engine promises an improvement in the overall efficiency of high-subsonic transport aircraft sufficient to warrant further serious investigation.

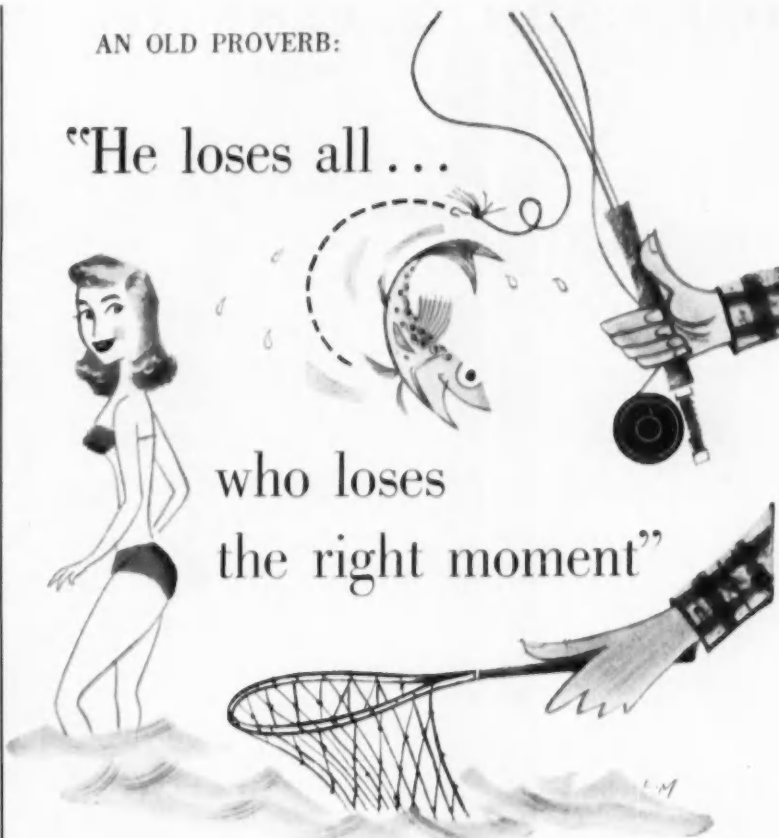
To realize the efficiencies promised, there are very sound reasons for using ratios of augmentation (weight ratios of bypassed air to heated-stream flow) between one and three. These were the ratios tried out in earlier engines.

A British engine had one feature which is still regarded as having great potential significance because it could make development of the ducted-fan engine economically feasible. The augmenting turbine and fan were added to an existing jet engine, thereby greatly reducing the time and cost of

AN OLD PROVERB:

"He loses all . . .

who loses
the right moment"



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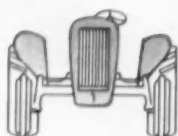
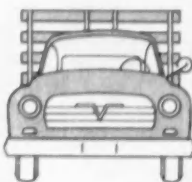
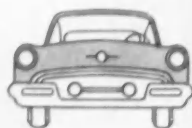
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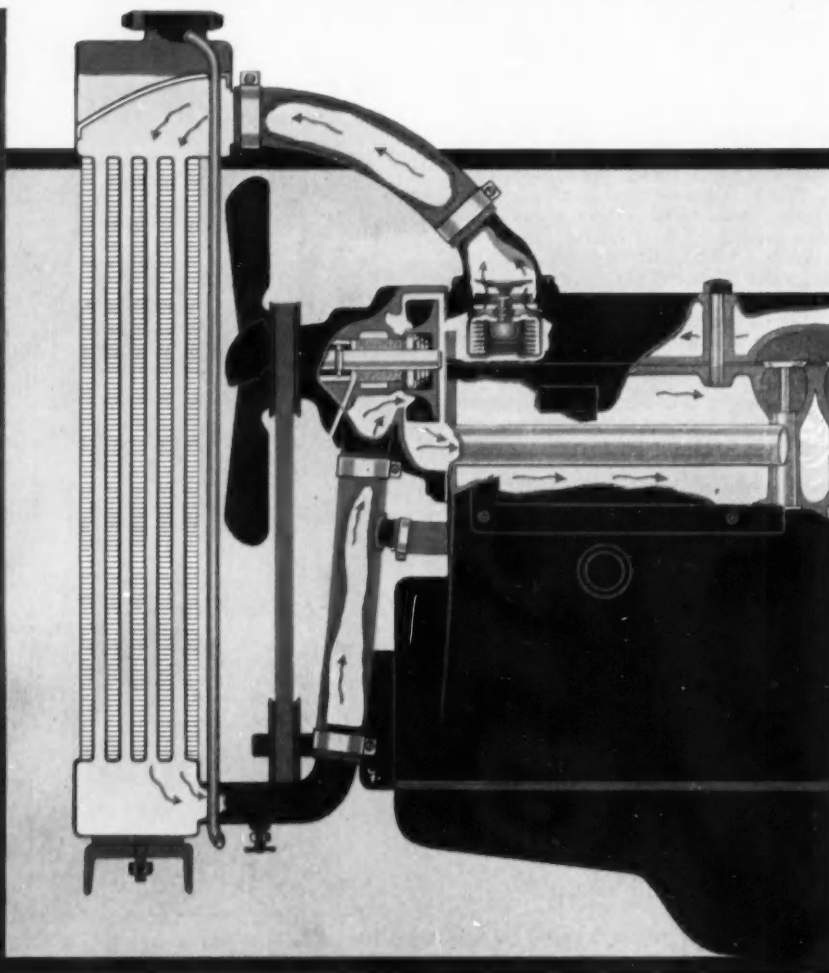

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RADIATOR DIVISION, GENERAL MOTORS CORPORATION, LOCKPORT, N. Y.

development. The Packard ducted-fan-engine development (1945 to 49) had the same potential characteristic.

A study of ducted-fan engine potential should include an inquiry into the possibility of increasing efficiency by boundary layer intake. The merits of such an intake with standard jet engines have been examined repeatedly and the results have been disappointing. Among the reasons for this is the fact that the rate of flow through the engine for a given thrust is determined by the "specific impulse" of the engine which usually does not vary over wide limits. With the ducted-fan engine, however, the specific impulse becomes a design variable, depending primarily on the ratio of augmentation.

Efficiency advantages obtainable by boundary layer intake, as far as predictable on the basis of the propulsive efficiency of the engine, are not spectacular unless one considers far-reaching changes in the airplane design. Nevertheless they may be significant since they are additive to the efficiency advantages of the bypass or ducted-fan engine. The merits of boundary layer intake are known to go well beyond those of increased propulsive efficiency of the engine. Such increases are simply an additional advantage of boundary layer intake.

There exists, as well, good theoretical and experimental evidence that the ram efficiency of a boundary layer intake slot can be sufficiently high for practical application, and that such a slot can meet off-design conditions.

Finally, there is the advantage of reduced jet noise due to reduction in jet velocity. This may be another reason why the bypass engine occupies an important place between the standard jet engine and the propeller-driving gas turbine.

(Paper "Principles and Applications of Bypass Turbojet Engines" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 8, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members, 60¢ to nonmembers.)

Based on Discussion . . .

Bernard J. Mezger, Curtiss-Wright Corp.

The greatest risk in the use of the bypass engine appears to be in its great sensitivity to small changes in the efficiency of the inlet and perhaps other components. This serves to explain in large part why the off-design performance can become so poor, for as the components move off their peaks the sensitive overall performance changes drastically.


Off-design performance becomes most important in any full operational use and suggests that variable blading or the introduction of an additional control variable may be a prerequisite to the successful development and uti-


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lization of the potential efficiency advantages theoretically available with a bypass engine.

H. Pearson, Rolls-Royce, Ltd.

A very attractive feature of the bypass engine is its lower noise level for a given take-off thrust compared with normal jet engines. Tests with an actual engine show about 7 db reduction, which is significant.

There are worthwhile gains in the

installation. The engine consists of the usual jet engine components surrounded by a complete sheath of relatively cool air. This should reduce the amount and weight of fire-prevention gear. For military use we can foresee an engine weight reduction of some 3 to 4% and a gain of 1 to 2% in engine thrust, due to reduced ventilation drag.

S. G. Hooker, Bristol Aeroplane Co., Ltd.

British bypass engines have operated

on augmentation ratios of 50 to 60%. Much higher ratios will be required to cash in on the engine's potential.

The ducted fan portion of the engine should definitely be at the front end of the engine in order to take full advantage of its possibilities for supercharging the compressor, and to retrieve some of the inevitable loss in air-specific power which the ducted fan suffers.

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Estimating Noise Complaint Potential

Based on paper by

R. H. BOLT

Massachusetts Institute of Technology

STUDY of noise and its effect on human beings shows the possibility of estimating the complaint potential and perhaps even the annoyance potential. But as yet it is impossible to pre-determine individual or community adverse reaction which depends on psychological variables.

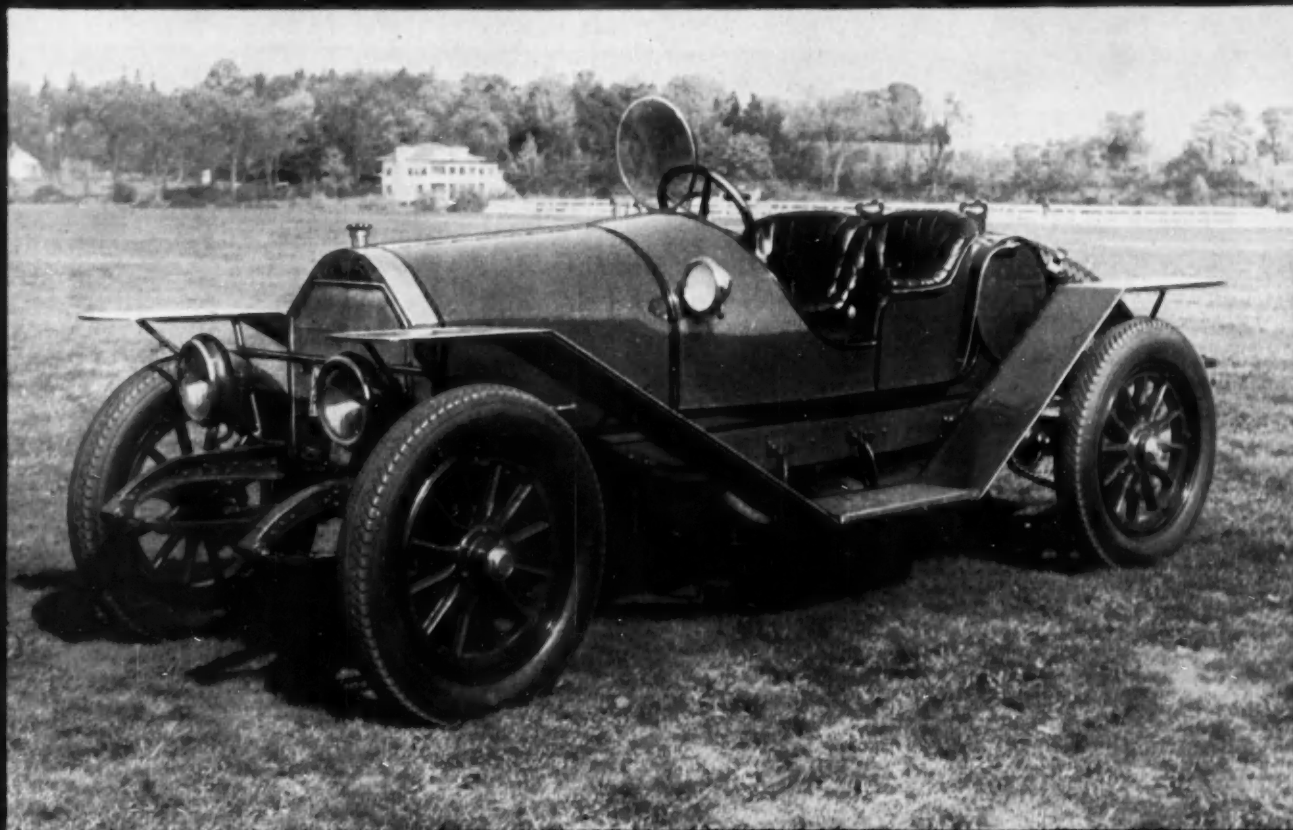
In general, the complaint potential increases with the increase in the noise level and its duration. Noise at night is worse than noise in the daytime; sharp noises are more annoying than those that build up gradually. The frequency spectrum of the noise and the usual background noises to which a community has become accustomed influence the complaint potential.

The reasons why noise is disturbing are:

1. Warnings of danger
2. Threats of reducing property values
3. Waking people from sleep
4. Scaring children
5. Intrusion of privacy
6. Reminder of something distasteful

People's attitudes can be modified over wide limits by appropriate education, public relations, acts of good will, expressions of sympathy, and just the therapy of letting people talk. These approaches cannot solve all noise problems, but they can be effective in stemming the tide of public reaction to aviation noise.

(Paper "Human Engineering Aspects of Aviation Noise Control" was presented at SAE Golden Anniversary Aeronautic Meeting, New York, April 19, 1955. It is available in full in multilith form from SAE Special Publications Department. Price: 35¢ to members; 60¢ to nonmembers.)



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This "streamlined" 1913 Simplex was almost totally hand-made, with all vital parts of imported chrome-nickel steel. It had a water-cooled, four-cylinder engine rated at 50 h.p., a 126½-inch wheel base, and a double-side chain drive.

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Over 60,000,000 Morse Timing Chains insure long service life of cars, trucks, and busses

Manufacturers of thirteen of the seventeen cars which now use timing chain drives specify *Morse Timing Chain Drives* as original equipment. Over the years, more than 60,000,000 of these drives have been supplied by Morse to the auto industry!

Precision-built Morse drives give car, bus, and truck owners long service life—plus freedom from maintenance worries.

If you have problems involving timing chain in design, development or

application, check first with Morse. We have expert engineering service available to help you solve them quickly, profitably.

For further information, call, wire, or write: MORSE CHAIN COMPANY, 7601 Central Avenue, Detroit 10, Michigan.

MORSE



**CHAINS, CLUTCHES,
AND COUPLINGS**

New Members Qualified

These applicants qualified for admission to the Society between June 10, 1955 and July 10, 1955. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

Atlanta Section

Robert Brown (J).

Baltimore Section

Harvey R. Miller (A), Winfred L. Shirley (A).

Buffalo Section

John R. Utz (M).

Canadian Section

Charles H. Barrett (M).

Central Illinois Section

Andrew B. Johnson (M).

Chicago Section

Harold L. Anson (J), Joseph A. Basile Jr. (A), Warden T. Blair, Jr. (M), Richard Chrzanowski (M), Robert H. Dawson (M), Harold R. Johnson, Jr. (M), Arthur R. Kernen, Jr.

(M), George C. Reynolds (A), Emil G. Stanley (A), William S. Wade (A).

Cincinnati Section

George E. Fouch (M), Guy C. Shafer (M).

Cleveland Section

Howard T. Griffith, Jr. (A), Charles Henick (J), Michael Lacko (M), George W. Price (A), Frank L. Raggi (A), Donald R. Wilcox (M).

Colorado Group

George Shellenberger (A).

Detroit Section

Robert C. Andrews (M), Arthur Mark Brewer (A), David N. Buell (M), N. E. Chrisfield (J), Walter Chupa (M), Charles E. Cochran (A), Edwin J. Durand (M), Archibald D. Evans (M), James P. Falvey (A), Charles J. Griswold, Jr. (J), Manfred A. Isaacson (M), Robert L. Jenkins (J), Lloyd A. Johnson (J), Paul R. Jones (A), Charles Kurland (J), Henry C. Maskey (M), Phillip Huff Maxwell (A), James C. McInnis (J), Stewart R. Peebles (M), Milford E. Prather (M), Edward Redmond (A), Henry T. Schlachter (A), Lyle Donald Sheckler (J), Eugene S. Sherman (J), Henry J. Wezner (A), Norbert P. Worden (M).

Hawaii Section

Lawrence R. Pestal (M).

Indiana Section

William Paul Bowman, Jr. (M), Robert L. Floyd (A).

Kansas City Section

T. Nicholas Bath (M), James A. Martin (M), James J. Wagner (A), Frank W. Walkup (A).

Metropolitan Section

Jean Roland Esquerre (J), Sam E. Fast (A), Cranston W. Folley (M), Vincent A. Hines (J), Raymond Petretti (J), Clifford A. Scantland (A), Edmund M. Storer, Jr. (M), Earl A. Venstrom (M).

Mid-Michigan Section

Gunnar John Anderson (A), Jack H. Anderson (J), Richard R. Crockett (M), Victor V. Greening (M), David M. Gurney (M), Leonard M. Morrish (M), Howard L. Roat (M), Harold J. Stanford (M).

Milwaukee Section

Eldon Myron Brumbaugh (J), William R. Bryant (J), George K. Isaacs (M).

Montreal Section

Joseph Napoleon Frenette (M), Lucien Guertin (J), Lorne Holtby (J).

Northern California Section

Garth Ray Neikirk (M), Lawrence A. Patrick (M).

Philadelphia Section

Ralph M. Hill (M), Salvatore F. Pisale (M), Leon B. Rosseau (M).

San Diego Section

L. E. Ottem (M).

Southern California Section

Paul E. Beattie (A), Ivan E. Gunton (A), Earl Leon Hodson (A), Charles A. Hofflund (M), Richard Melvin Jones (A), John P. Klockslem (M), Richard W. Larkin (A), Donald Horigan Stewart (M), Stanton F. Wiswell (A), R. Stanley Wright (M).

Southern New England Section

Donald G. Brubaker (M), Winston H. Sharp (M).

Syracuse Section

William A. Kinnaman (M).

Texas Section

Farrald G. Belote, Sr. (M), F. W. Brizzolara (M), Lyman C. Josephs, III (M), Ben E. Poppe (A), R. B. Tuggle (A).

Texas Gulf Coast Section

Wilbur Hans Cooper (M), Morris R. Morrow (M), Edward F. Wadley (M).

SINCE 1907

“PARK”

THE SYMBOL FOR

**QUALITY
IN
DIE FORGINGS**

FROM VITAL AVIATION DROP FORGINGS
TO **DIESEL CRANKSHAFTS**
WEIGHING UP TO 4000 LBS.

THE PARK DROP FORGE CO.
E. 79th & GORDON PARK
CLEVELAND 3, OHIO

A Good Team to Team with

...BEFORE FREEZING YOUR NEW MODEL DESIGNS FOR PRODUCTION



Having literally grown up with America's No. 1 industry, Aetna, today, is a preferred supplier of a wide range of ball and roller bearings and custom-made parts for nearly every type of on-and-off-the-road automotive vehicle.

Why? First, we believe, it is because of the consistent, superior performance of our products . . . secondly, because of the exceptional creative engineering efforts we put behind the job of serving manufacturers—to help improve their products, assure speedy assembly and reduce costs. This, we feel, adds up to a good way of doing business . . . makes us good people to do business with. We hope you will try it and see.

Aetna

AETNA BALL AND ROLLER BEARING COMPANY

DIVISION OF PARKERSBURG-AETNA CORPORATION

4600 Schubert Avenue • Chicago 39, Illinois
In Detroit—Sam T. Keller, 2457 Woodward Ave.

Standard and Special Ball Thrust Bearings • Angular Contact Ball Bearings • Special Roller Bearings • Ball Retainers • Hardened and Ground Washers • Sleeves • Bushings • Miscellaneous Parts

New Members Qualified

continued

Twin City Section

Michael Kaminsky, Jr. (J).

Virginia Section

Linwood W. White (A).

Washington Section

J. Pitts Jarvis, Jr. (M), Brig. Gen.
Benjamin S. Kelsey (M).

Western Michigan Section

Clarence Alvin Chase (A).

Williamsport Section

Elwood O. Avery (M).

Outside Section Territory

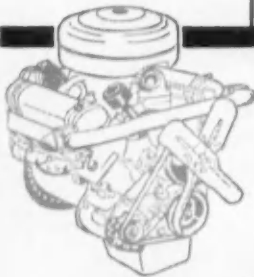
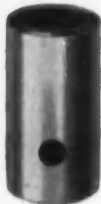
J. R. Allen (J), James F. Coyle (J).

George L. Henwood (M), E. F. Koenig
(M), Ernest J. Richards (M).

Foreign

Einar Gustaf Bohr (M), Sweden;
Jacques Y. Levoyer (M), France; Ken-
neth A. Schubert (A), India; Swamy
Kempiah Venkat (A), India.

JOHNSON *tappets*



keep pace with today's engines

Continual experimentation and excel-
lent manufacturing methods show a steady
product improvement that make JOHNSON
TAPPETS worthy of your consideration.

Only proven materials, covering a range
of steel, chilled iron, and various iron alloys are
used in the manufacture of JOHNSON TAPPETS, providing greater
strength, light weight and increased wear resistance.

Serving the AUTOMOTIVE — AIRCRAFT — FARM —
INDUSTRIAL — MARINE Industries.

"tappets are our business"

JOHNSON *JP* PRODUCTS
MUSKEGON, inc. MICHIGAN

Applications Received

The applications for membership
received between June 10, 1955 and
July 10, 1955 are listed below.

Alberta Group

William R. Davis.

Atlanta Section

Verney E. Bentley, Jr., James L.
Broom.

Baltimore Section

Ward M. Carpenter

Canadian Section

Thomas J. Maloney, Donald E.
McLean, Robert J. I. Scott, Fred C.
Walter.

Central Illinois Section

Joseph T. Gregorich, Fred C. Hansen.

Chicago Section

Ellis John Airola, Lawrence Alan
Durling, Carl John Eichinger, Roger
R. Gay, Norman L. Ginder, Thomas
M. Holland, James S. Hurrell, Frank
E. Kalivoda, Jr., Waldemar C. Lind-
strom, M. J. Marty, Jr., John A.
Rassenfoss, John Rusnak, Gunter W.
Schwandt, Ben D. Smith, Leo G.
Weaver.

Cincinnati Section

David Cochran, Rowland James Hill.

Cleveland Section

James A. Bailey, Jr., James L. Bax-
ter, William A. Compton, William W.
Peters, Warren D. Waldron.

Dayton Section

Earl W. Reinsch, Vernon L. Schatz.

Detroit Section

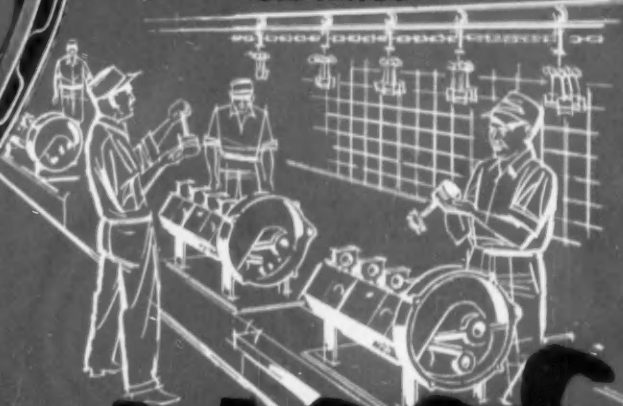
George E. Bisbee, H. P. Cardon,
Peter M. Dawson, Edmund Charles
Decker, Alvin P. DuDeck, David H.
Edwards, Richard M. Graham, Albert
J. Graumlich, Ivan W. Hansen, Donald
J. Hawk, Edmund Murray Hilton,
Frederick C. Koch, Leon P. Kocol, Carl
F. Kop, E. Kendrick Leavenworth,
Denis L. Lenane, Lawrence E. Podnar,
Carl F. Stieler.



CSR-200

First of Muskegon's famous "Unitized" chrome-plated multiple-piece oil rings... proved on America's greatest production lines and in the finest cars. Rails and spacer are correctly pre-assembled and "Unitized" to handle like a one-piece ring.

MUSKEGON "UNITIZED" CHROME-PLATED OIL RINGS



error-proof

...installs faster than any other multiple-piece ring... and without special installation tooling!

To err is human — and *very costly* on the assembly line. But Muskegon's "Unitized" Piston Rings greatly reduce this cost because they are *always* correctly assembled, handle like a one-piece ring and install faster than any other multiple-piece ring — without special installation tooling.

And what's more, Muskegon gives you *two* "Unitized" oil ring designs to choose from. The CSR-200, Muskegon's chrome-plated, all-steel, pre-assembled oil ring, has set new standards on the production line for faster, more economical and error-proof installation. Now the all-new CSR-400 offers all of the features of the CSR-200, *plus* the advantages of a revolutionary new circumferential expander.

The secret of their success is better design and Muskegon's patented "Unitizing" process. This process holds the pieces together in the right order for quick, easy installation. Then, in the first rush of hot oil, as the engine starts to run, the special adhesive dissolves completely and leaves the parts free to function independently of each other. The chrome-plated rails reduce ring wear and bore wear, scuffing and friction... keep the engine new longer and increase oil economy.

But why take anyone's word for it but your own? Get the facts on Muskegon's CSR-200 or new CSR-400 rings for your engines.



new CSR-400

Muskegon's most recent development... CSR-400 chrome-plated oil ring with circumferential expander! All four pieces are "Unitized," a Muskegon exclusive, for easy handling and installation.

Write us today.

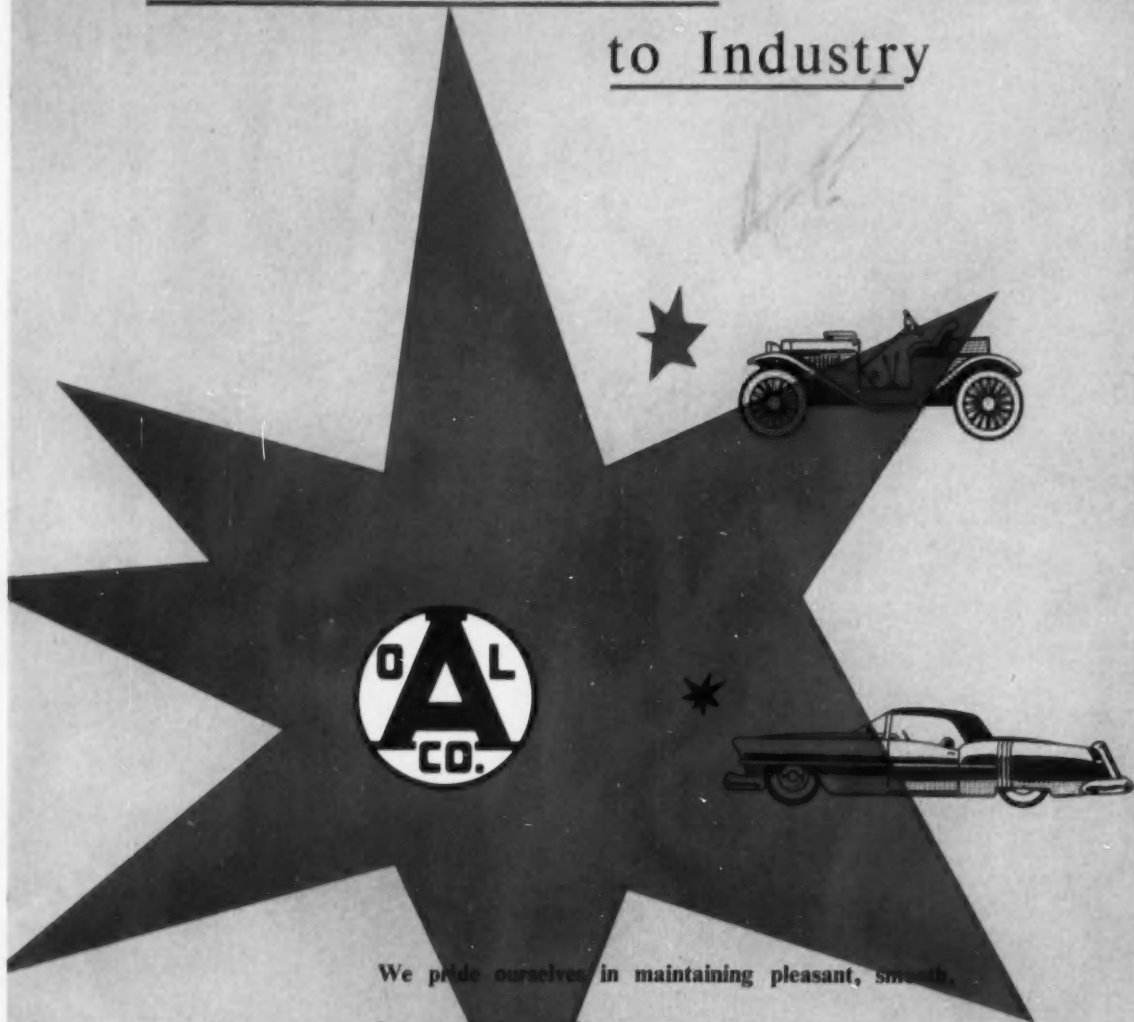
DETROIT OFFICE:
521 New Center Bldg.
Telephone: TRinity 2-2113

MUSKEGON Piston Rings

MUSKEGON PISTON RING CO.
MUSKEGON, MICHIGAN
PLANTS AT MUSKEGON AND SPARTA

Since 1924... The engine builders' source!

36 Years of Service
to Industry



We pride ourselves in maintaining pleasant, smooth,
honest relations with our customers.

Over the years we have endeavored to hold to a policy
of reasonable promises and prompt execution of contracts.

O. L. ANDERSON CO. Inc.
MANUFACTURERS OF

FUEL TANKS AND SHEET METAL ASSEMBLIES
for the AUTOMOTIVE INDUSTRY

1347-87 EAST FORT STREET



DETROIT 7, MICHIGAN

Applications Received

continued

Indiana Section

Walter A. Brighton, Howard J. Jordan, C. A. Kenninger, Richard J. Turner.

Kansas City Section

G. T. Hahn, R. B. Speirs.

Metropolitan Section

Edward W. Bradley, Leonidas M. Calhoun, Robert J. Eden, Brian Perse Emerson, Martin Freedman, Arthur R. Heydorn, Max A. Labhart, Francis L. LaQue, Harold L. Murphy, John G. Pohl, Jr., Eugene P. Valley, Joseph Warrington, Lawrence K. Wartell, Cyrus F. Wood.

Mid-Continent Section

A. J. Snyder, Raymond F. Spender.

Mid-Michigan Section

John W. Gustke, Cordy M. Russell.

Montreal Section

Francis V. Guimont, Jean M. H. Helnes, Clarence Sheppard.

New England Section

Harold B. Gordon, Bruce P. Hoffman, William J. McIsaac.

Northern California Section

Syed V. Husain.

Northwest Section

Arthur G. Walden.

Oregon Section

Leslie L. Aldrich.

Philadelphia Section

Arthur P. Bray, Howard C. Freeman, Walter E. MacDonald, William R. Miller, Alexander S. Simitch.

Pittsburgh Section

Laurence A. Keim, James Kenneth Seatter, Russell G. Whittemore.

St. Louis Section

Robert T. Lintern, Bernard J. Verna.

San Diego Section

Richard L. Andre, Raymond C. Sebold, Clarence Waltner, Jr.

Southern California Section

Gerald G. Boruski, William G. Brown, John H. Camlin, Julian Caranza, William S. Coleman, Donald Eugene Eddy, Walko E. Gasich, E. B. Reynolds, Joseph Henry Shirar, Don G. Smith, Robert Burton Stewart, Charles S. Wagner.

Southern New England Section

Robert F. Ostrander.

Twin City Section

Neil F. Brown, David T. Turner.

Washington Section

S. K. Padam.

Wichita Section

J. M. Tucker.

Outside of Section Territory

Harry J. Charette, William Gaston Gove, Ray L. Heffelfinger, Jr., Melvin J. Helmich, Alfred T. Sutter, James O. Troemner, Alfred Weiner, Robert Ted Wright.

Foreign

Pieter Drayer, Holland; Vernon E. Gough, England; Helmut Emil Hautle, Venezuela; John L. B. Murray, South Africa; Karl-Heinz Schmidt, Germany; Torsten R. Verkkola, Finland.



The S.S.White swaging method revolutionized the making of speedometer cable ...

S.S.WHITE "FIRSTS"

have meant better, more economical speedometer cable

FIRST to pioneer the use of flexible wire wound cable.

FIRST to introduce automation in speedometer cable manufacturing.

FIRST to develop machines for arc-cutting speedometer cable.

FIRST to introduce integral drive squares.

FIRST to develop satisfactory swaging equipment for speedometer cable.

FIRST to develop small diameter, thin wall speedometer casing.

FIRST to introduce galvanized casings for speedometer service.

S.S.WHITE INDUSTRIAL DIVISION
10 East 40th Street, New York 16, N. Y.

Making speedometer cable is a complex, exacting business, which not only calls for specialized equipment, but the "know-how" to go with it.

Take the problem of forming the integral drive square, currently used on all speedometer cable. The old method, using a two piece die was costly and unreliable. Maintenance of dies was high, it was difficult to maintain correct tolerances and it took at least four (and sometimes six or seven) blows of the press to produce a good square.

As has often been the case in speedometer cable design and manufacture — S.S.White furnished the answer ... the S.S.White Squaring Fixture No. 10 which formed an accurate square with a single stroke of the press — which assured close tolerances on high production runs — and which practically eliminated all maintenance of dies and equipment.

The S.S.White Squaring Fixture No. 10 is now the standard of the industry and is used by all speedometer manufacturers.

FIRST NAME

S.S.White

in flexible shafts for speedometer drives, industrial power drives and remote control.

ARMASTEEL

ArmaSteel is a versatile pearlitic malleable iron that combines the advantages of both castings and forgings. ArmaSteel parts can be cast by conventional sand method or shell mold process to relatively close dimensions in large quantities at low cost. Because of the excellent, accurately controlled physical properties of ArmaSteel, these parts have the strength and performance characteristics usually associated with plain carbon steel forgings.

ArmaSteel is produced in three ranges: ArmaSteel 84M, ArmaSteel 85M and ArmaSteel 86M with a wide variety of physical properties uniformly maintained through accurate heat treating operations as follows:

ARMASTEEL 84M is recommended where a high degree of strength is necessary. It usually replaces heat-treated steel parts in the 1040-1050 S.A.E. range. It has a hardness range of BHN 241-269 or 3.7-3.9 mm. impression with a 3000 Kg. load. Tensile strength is 100,000 p.s.i., yield strength is 80,000 p.s.i., and percent of elongation in 2" is 2.0%.

ARMASTEEL 85M is recommended where moderate strength is required and where selective hardening is necessary. This class usually replaces parts in the 1035-1050 S.A.E. range. It has a hardness range of BHN 197-241 or 3.9-4.3 mm. impression with 3000 Kg. load. Tensile strength is 80,000 p.s.i., yield strength is 60,000 p.s.i., and percent of elongation in 2" is 3.0%.

ARMASTEEL 86M is recommended for less highly stressed parts usually replacing steel parts in the 1020-1035 S.A.E. range. It has a hardness range of BHN 163-207 or 4.2-4.7 mm. impression with 3000 Kg. load. Tensile strength is 70,000 p.s.i., yield strength is 48,000 p.s.i., and percent of elongation in 2" is 4.0%.

MACHINABILITY OF ARMASTEEL

ArmaSteel's machinability makes it outstanding in the ferrous field. In general, its rating is from 10% to 30% better than bar stock or forgings of the same Brinell hardness. One of the reasons for this rating is the structure, which consists of a matrix of sorbitic-pearlite and spheroidized cementite in which small nodules of carbon



a triumph of modern metallurgy

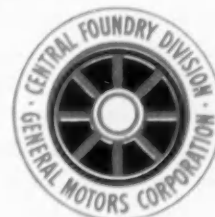
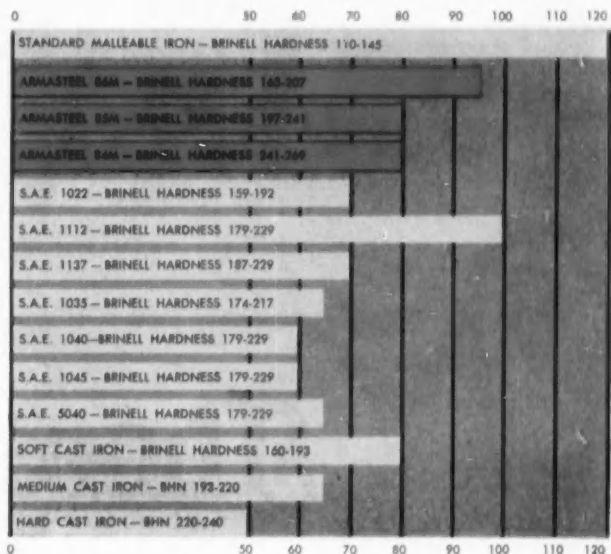
are imbedded. Because of this the chips break off more readily in machining operations whether it be turning, drilling, milling or broaching.

The machinability rating of a metal is not absolute—its rating can be stated only in relation to that of another metal. To establish the accompanying machinability rating table Bessemer screw stock S.A.E. 1112 is used as the base. In establishing these ratings, the cutting speed of the S.A.E. 1112 is the rate generally used in turning this metal on automatic screw machines. The rate of feed, however, is altered to that necessary to attain normal tool life and good surface finish when using a coolant. When the other metals are tested, the feeds and speeds are varied from these basic rates to whatever rate is necessary to obtain comparable tool life and comparable surface finish. The ratio of these rates of speeds and feeds of each tested metal determines the percentage of machinability.

The FIVE parts illustrated below are typical of the hundreds of different parts and products successfully produced in ArmaSteel for many diversified industries.

Write, today, for new 70 page comprehensive catalog.

MACHINABILITY RATING (PER CENT)



50 A

CENTRAL FOUNDRY DIVISION
GENERAL MOTORS CORPORATION
SAGINAW, MICHIGAN

Whether it's steering linkage parts for

a 1928 auto...



...for today's
production models...

or that 195~~8~~ experimental job...

You can count on



Thompson

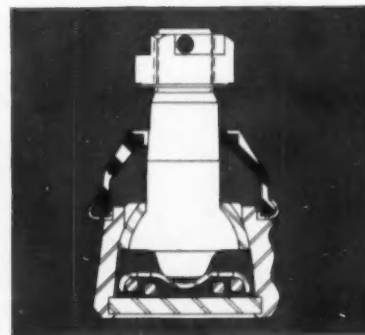
YES, manufacturers of automobiles, trucks, tractors and buses look to Thompson for a long list of dependable parts.

The Thompson Dual Bearing tie rod end is typical of Thompson Products' contribution to today's automobile. Among the many other Thompson products found on today's automobiles are the revolutionary new Thompson-engineered Ball Joints used in front wheel suspension and complete steering linkage units.

And typical of Thompson's dependability as a source of supply is the fact that Thompson is still manufacturing replacement steering linkage units for cars up to 27 years old.

Tomorrow's cars will use Thompson products, too, because automo-

tive manufacturers have learned they can count on Thompson to develop and manufacture dependable parts. If you use steering linkage units, why not use "Steering Linkage by Thompson". For full details on how Thompson can help you with your steering linkage problems, write, wire or phone Thompson Products, Inc., Michigan Division, 7881 Conant Avenue, Detroit 11, Michigan, WA 1-5010.



A Tie Rod End ball stud should fit snug in the socket. Any tie rod end starts that way but the extra bearing surface in the Thompson Dual Bearing tie rod end keeps the stud snug in the socket far longer.

Thompson Products

MICHIGAN DIVISION

DETROIT • FRUITPORT • PORTLAND

modern design specifies stainless steel

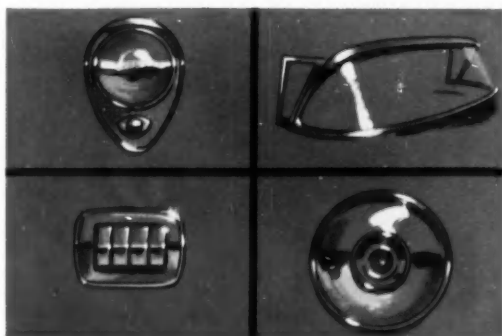


McLouth STAINLESS **Steel**

for automobiles

The beautiful bright molding and trim that style your car are made of non-corrosive, easy to clean Stainless Steel. Designers of automobiles and hundreds of other products specify Stainless Steel for its many valuable properties.

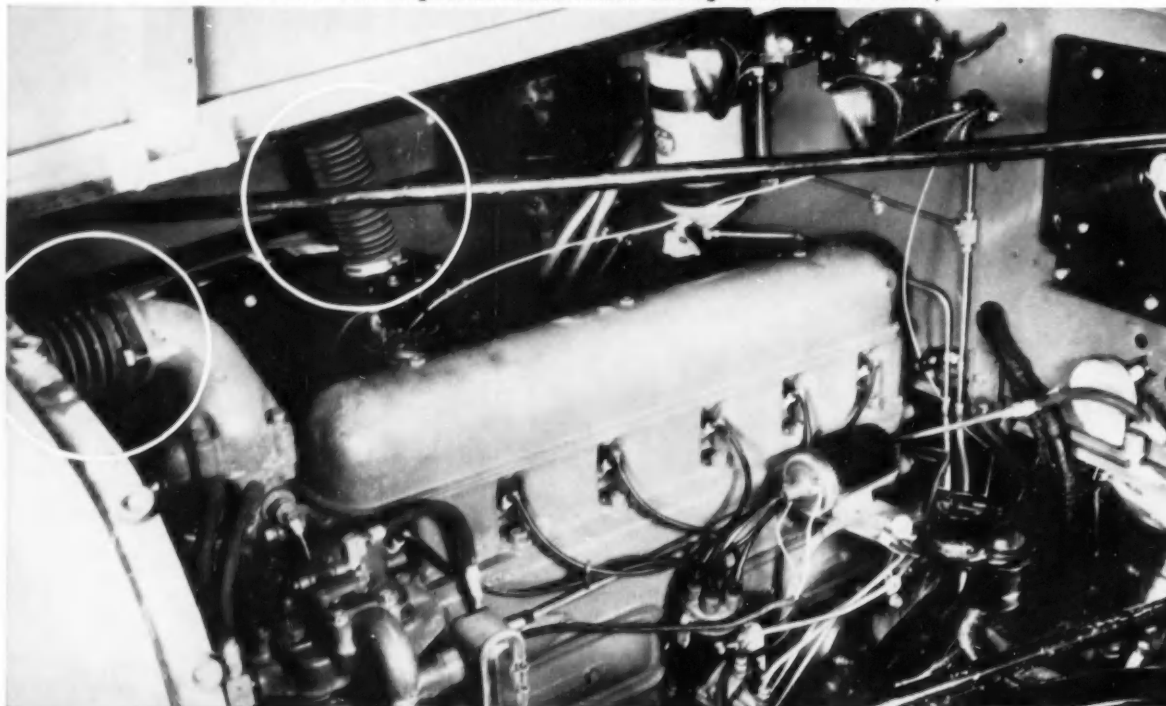
For the product you make today and the product you plan for tomorrow specify McLouth high quality sheet and strip Stainless Steel.



McLOUTH STEEL CORPORATION
Detroit, Michigan

MANUFACTURERS OF STAINLESS AND CARBON STEELS

Another "U. S." Engineered Rubber Product serving the automotive industry



U. S. MULTI-FLEX connectors

take up the stress and strain of engine vibration

U. S. Multi-Flex® connectors are flexible, accordion-like parts that "give"—thereby relieving automotive piping from the strain and fatigue brought on by engine vibration and torque reactions, bumps, quick starts, sudden stops.

Here Multi-Flex is shown as a connection between the cast tubular line from the radiator and engine tubular line. Here Multi-Flex allows the engine to move without transmitting force, both laterally and fore and aft on the radiator. A rigid piece of hose would exert great leverage force on the radiator and radiator tank.

Multi-Flex is used on carburetor air intakes, as boots for hydraulic pistons, shock absorbers, worm gears and sensitive adjusting screws, exhaust outlets, and many, many more. The Multi-Flex boot has an extension-compression ratio of over 3 to 1—without

the strain or fatigue that quickly destroys other types of so-called "flexible" tubing.

Natural or synthetic rubber Multi-Flex can be fabric-reinforced, since it's made without molds, special mandrels or supporting wires. It can be produced in inside diameters from $\frac{1}{8}$ " to 36" in required lengths. Can be constructed to withstand temperature range of -65°F to 500°F.

Multi-Flex is available with flanges at either end; it also can be fastened in the conventional manner with clamps. Unlike wire-supported hose, it can be repeatedly crushed without damage. For all-around flexibility, for the smoothest "travel" in a connector, specify Multi-Flex. Most samples for experimental use can be made without tooling charges. For samples and engineering service, phone us in Detroit at Trinity 4-3500.



"U.S." Research perfects it... "U.S." Production builds it.

UNITED STATES RUBBER COMPANY
Automotive Sales, Mechanical Goods Division • New Center Bldg., Detroit 2, Michigan

SAGINAW ANNOUNCES:

A REVOLUTIONARY "FIRST"—THE WORLD'S ONLY BALL BEARING **SPLINE!**



New Saginaw b/b Spline makes all ordinary splines obsolete!

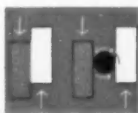
By applying the flight-proved principle of the recirculating rolling ball (already made famous by the *Safety b/b Screw*), Saginaw has revolutionized spline design! The new *Safety b/b Spline* is so far superior to any spline ever before built that aircraft engineers are adopting it with open arms—particularly for landing gear applications, where it's a "natural".

In any application where column length must change under torque load, the *Safety b/b Spline* offers unprecedented freedom from spline restrictions.

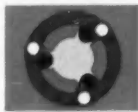
AVAILABLE IN ALMOST ANY SIZE

Every *Safety b/b Spline* is individually engineered for its particular application, with the wealth of know-how that only Saginaw, the pioneer, can offer. Our engineers are ready and eager to help you.

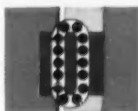
WHAT IT IS AND HOW IT WORKS:



Let's start with the familiar principle that there's far less friction in rolling than in sliding. The average coefficient of friction of the sliding spline is .2—while that of the ball-bearing spline is only .005.



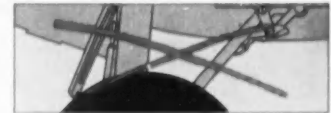
By applying this principle, the *Safety b/b Spline* radically increases the efficiency of transmitting or restraining high torque loads. Instead of sliding against each other, the mating surfaces glide on rolling balls.



The steel balls recirculate in closed circuits formed by mating longitudinal raceways spaced around the circumference of both the inner and outer splines. Ball guides return the balls to their starting point.



HOW THE *Safety b/b Spline* CAN HELP SOLVE YOUR AIR- CRAFT ACTUATION PROBLEMS



The *Safety b/b Spline* offers great advantages over the conventional "scissors" unit in landing gears.

The coefficient of friction of the *Safety b/b Spline* is approximately 40 times better than that of the conventional spline. It can be fitted with integral gears, clutch dogs, bearing and sprocket seats or other attachments for use with electrical, hydraulic or pneumatic units—forming a unit with tremendous advantages for the aircraft engineer. It can enable you to:

ACHIEVE THE "IMPOSSIBLE"—By reducing weight and space requirements, the *Safety b/b Spline* permits engineering designs hitherto impractical.
INCREASE DEPENDABILITY—Greatly decreased friction means less wear—longer life—safer, more dependable operation is assured.

SEND FOR FULL DETAILS TODAY!

New *Safety b/b Spline Bulletin* includes design data to facilitate your preliminary planning. Just write on your company letterhead to:

Safety
ball bearing
Spline by **Saginaw**

STEERING GEAR DIVISION • GENERAL MOTORS CORPORATION • Saginaw, Michigan

Sensational Piston Performance

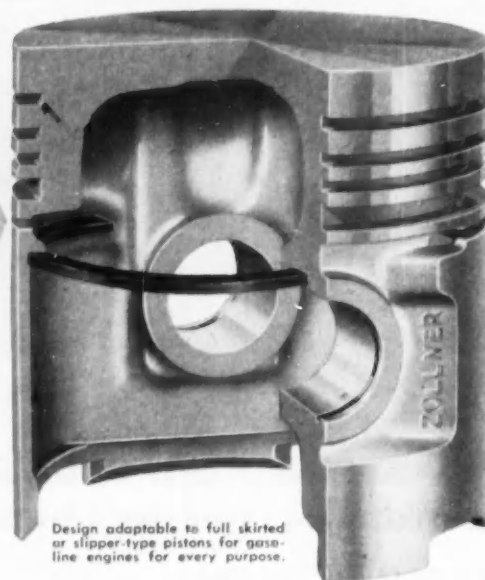
UNIFORM CLEARANCE AT ALL TEMPERATURES

STEEL TENSION MEMBER

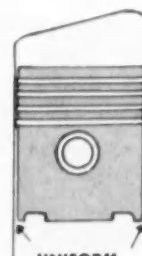
Anchored only at pin bosses
and cast in positive contact
with I. D. of piston skirt
Controls Clearance Automatically

ZOLLNER CLEAR-O-MATIC PISTONS

Now, pistons may be fitted to closer clearances than ever before possible. The sensational development of CLEAR-O-MATIC Pistons by Zollner engineers reduces required clearance to less than .001 with constant uniformity of skirt bearing over the entire temperature range. Performance results are spectacular. Engines run quietly with no cold slap. Friction is reduced without loss of durability or heat conductivity. There is no danger of scuffing or seizing. The Zollner designed steel tension member incorporates in the aluminum piston the same effective expansion as the ferrous cylinder itself. We urge your immediate test of these sensational advantages for your engine.



Design adaptable to full skirted or slipper-type pistons for gas-line engines for every purpose.



UNIFORM
EFFECTIVE SKIRT
CLEARANCE
AT ALL
TEMPERATURES

- 1 Clearance maintained uniformly at all coolant temperatures from 20° below zero to 200° F.
- 2 Effective expansion identical with ferrous cylinder.
- 3 Steel tension member, with same effective expansion as cylinder, maintains uniform skirt clearance through entire temperature range.
- 4 Normal diametric clearance usually less than .001 with uniform skirt bearing.
- 5 Durability and conductivity comparable to heavy duty design.

ZOLLNER THE ORIGINAL EQUIPMENT PISTONS
ZOLLNER
PISTONS

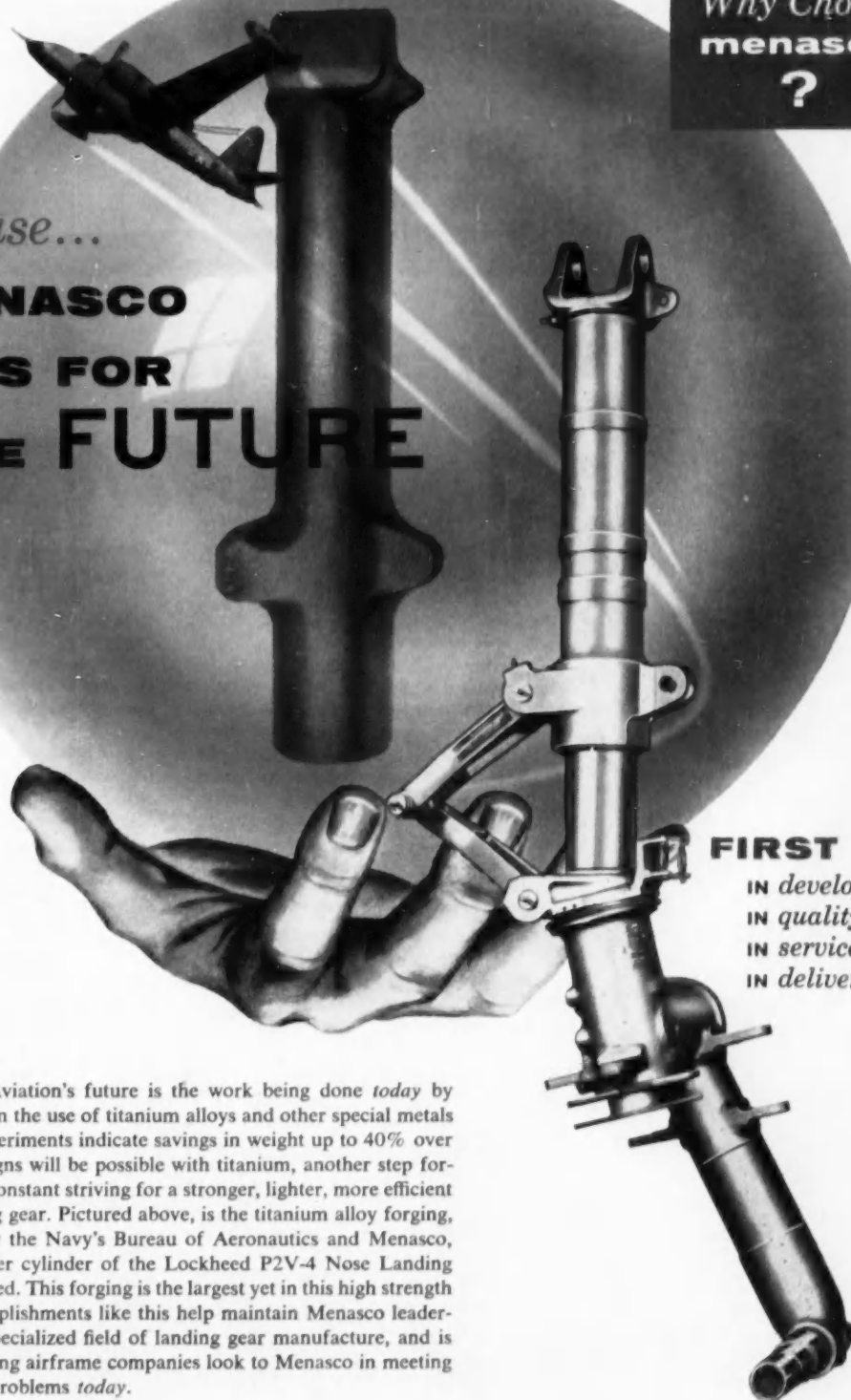
ZOLLNER MACHINE WORKS • Fort Wayne, Indiana

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- PRECISION PRODUCTION

in cooperation with
engine builders

Why Choose
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Because...
MENASCO
BUILDS FOR
THE FUTURE



FIRST
IN development
IN quality
IN service
IN delivery

Looming large in Aviation's future is the work being done *today* by Menasco engineers in the use of titanium alloys and other special metals in landing gear. Experiments indicate savings in weight up to 40% over certain existing designs will be possible with titanium, another step forward in Menasco's constant striving for a stronger, lighter, more efficient and compact landing gear. Pictured above, is the titanium alloy forging, developed jointly by the Navy's Bureau of Aeronautics and Menasco, from which the outer cylinder of the Lockheed P2V-4 Nose Landing Gear will be fabricated. This forging is the largest yet in this high strength alloy. Design accomplishments like this help maintain Menasco leadership in the highly specialized field of landing gear manufacture, and is the reason why leading airframe companies look to Menasco in meeting *tomorrow's* design problems *today*.



menasco manufacturing company

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Specialists in Aircraft Landing Gear



Riss Buys 500 **ROADRANGERS**

Riss & Company, Inc. of Kansas City, Mo., specified that every one of their new fleet of 500 tractors be equipped with a Fuller Semi-Automatic R-950-C ROADRANGER Transmission.

With single-lever control of all 10 forward speeds, the Fuller ROADRANGERS permit Riss drivers to anticipate grade requirements and meet them with the right ratio at the right time. The ten closely spaced ROADRANGER gear ratios can be readily anticipated and rapidly engaged,

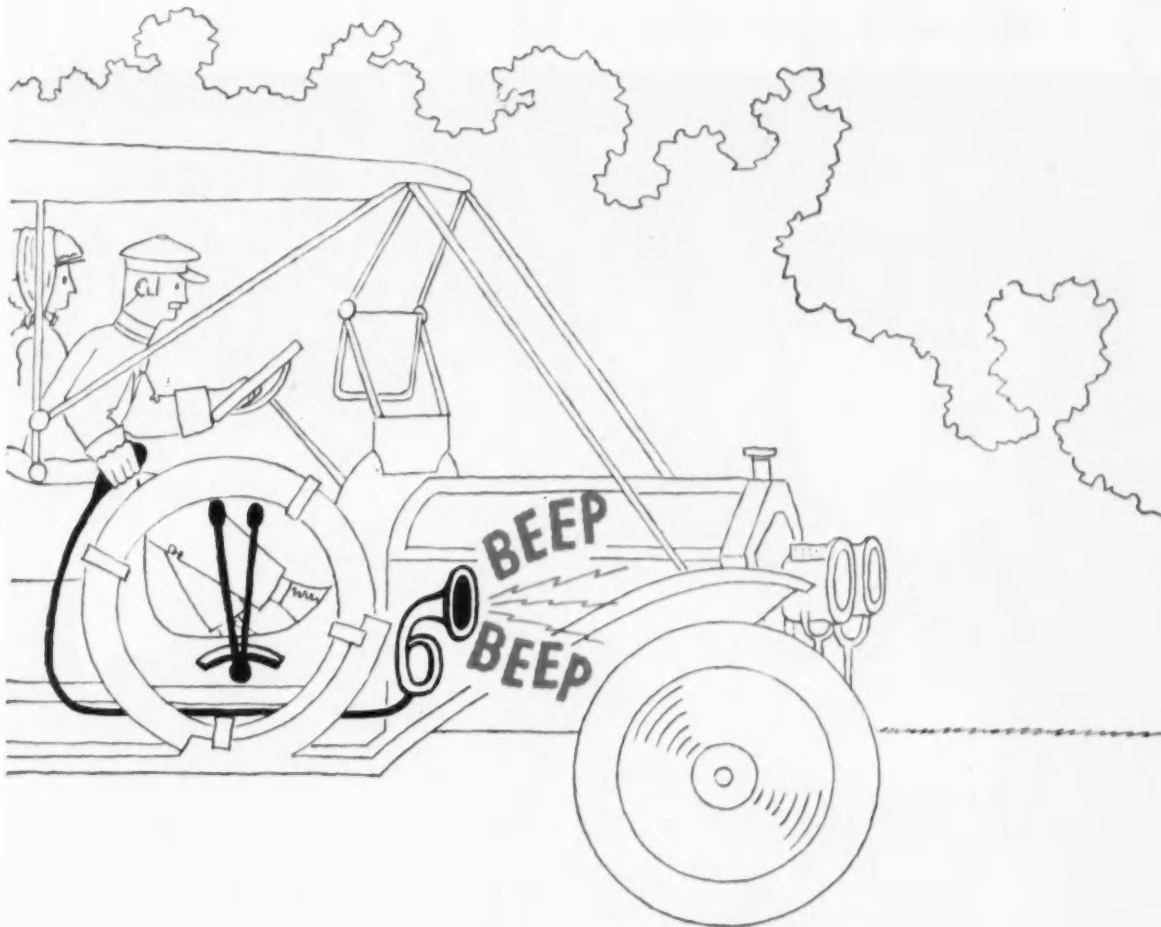
without having to wrestle with gear splits or wait for automatic actuation. And with all forward ratios in even 28% steps, they can match power precisely to load and grade demands and at the same time save fuel by keeping the engine operating in the maximum horsepower range.

For the most efficient, easiest-shifting transmissions available today . . . specify Fuller Semi-Automatic ROADRANGERS for your fleet!

FULLER MANUFACTURING COMPANY
(Transmission Division) Kalamazoo, Mich.



Unit Drop Forge Div., Milwaukee 1, Wis. • Shuler Auto Co., Louisville, Ky. (Subsidiary) • Sales & Service, All Products, West. Dist. Branch, Oakland 6, Cal. and Southwest Dist. Office, Tulsa 3, Okla.



Now there was a car horn . . . and when a red-blooded American boy, out riding with his girl, squeezed the bulb, he said, "I like the sound of that horn." But his lady love said, "It jangles my nerves."

So automobile manufacturers (who are red-blooded American boys themselves) changed the horn. And that's the way it's gone over the years.

Automobile manufacturers have introduced automatic transmissions, power steering, wrap-around windshields, and power brakes . . . style conscious, safety conscious women voiced their approval and went along with their husbands to help pick out the new car.

And today, women have indicated that driving would be even more pleasant with safer brakes. That's why we are certain that in the very near future you'll be driving a car equipped with Auto Specialties Double-Disc Brakes. Auto Specialties Double-Disc Brakes are designed to easily control today's more powerful cars. They make driving safer, drivers surer of their brakes. Auto Specialties Double-Disc Brakes are the most modern power brakes built. The extra power for braking is built right into the brakes themselves . . . they stop you more smoothly, more quickly, more gently. They have passed the severe braking tests of leading car factories. They're safer brakes and their adoption will be another step forward in the automotive industries' aim toward making driving more pleasant and safer for you, your wife and your family.

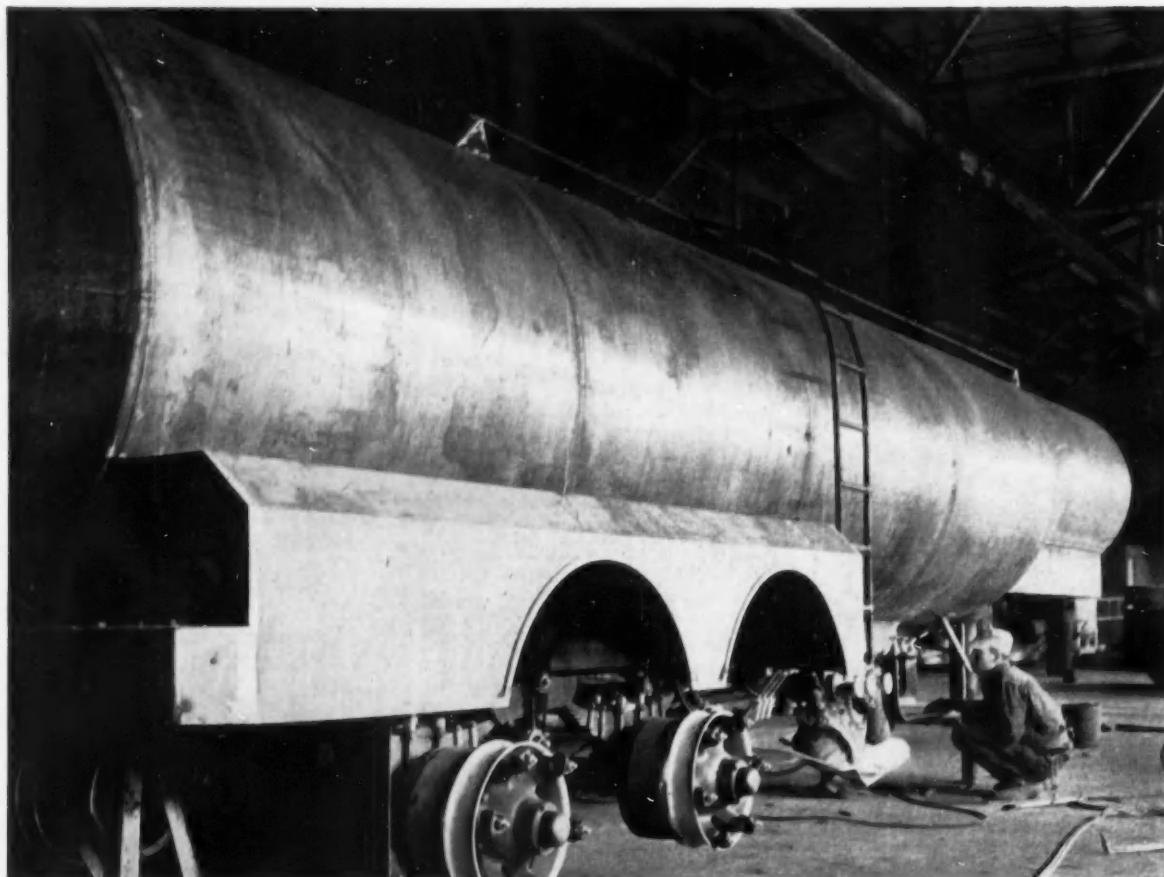
A 16-page, 4-color book, "The Stopping Story," gives detailed information about these brakes. It's free. Write for it to

AUTO SPECIALTIES MFG. CO., INC.

SAINT JOSEPH, MICHIGAN

Plants also at Benton Harbor and Hartford, Mich., and Windsor, Ont., Canada.
Manufacturing for the automotive and farm machinery industry since 1908.

Mayari R makes it lighter...stronger...longer lasting



Star Tank & Trailer cuts deadweight 10 pct with Mayari R tank sheets

These tankers were designed to carry casin-head gas, under 17 psi. However, their manufacturer, Star Tank and Trailer Manufacturing Company, Rhome, Texas, says they are equally adept at hauling petroleum in any liquid form.

The all-welded trailer shown here has a capacity of 6650 gallons. By using Mayari R, the Star people were able to meet loading requirements with lighter gage sheets, thus cutting down overall trailer deadweight by 10 pct. In addition, they furnished their customer with a more corrosion-resistant trailer which would hold up longer than a tank made of plain carbon steel.

Greater strength . . . superior corrosion-resistance . . . easy weldability . . . these are but a few of the advantages of high-strength, low-alloy Mayari R steel. Automotive vehicle manufacturers all over the country are making increased use of this versatile steel to the benefit of their



customers, and at a profit to themselves. Our Catalog 353 deals thoroughly with this subject of automotive applications. You can get a copy promptly by a request to the nearest Bethlehem sales office.

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BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
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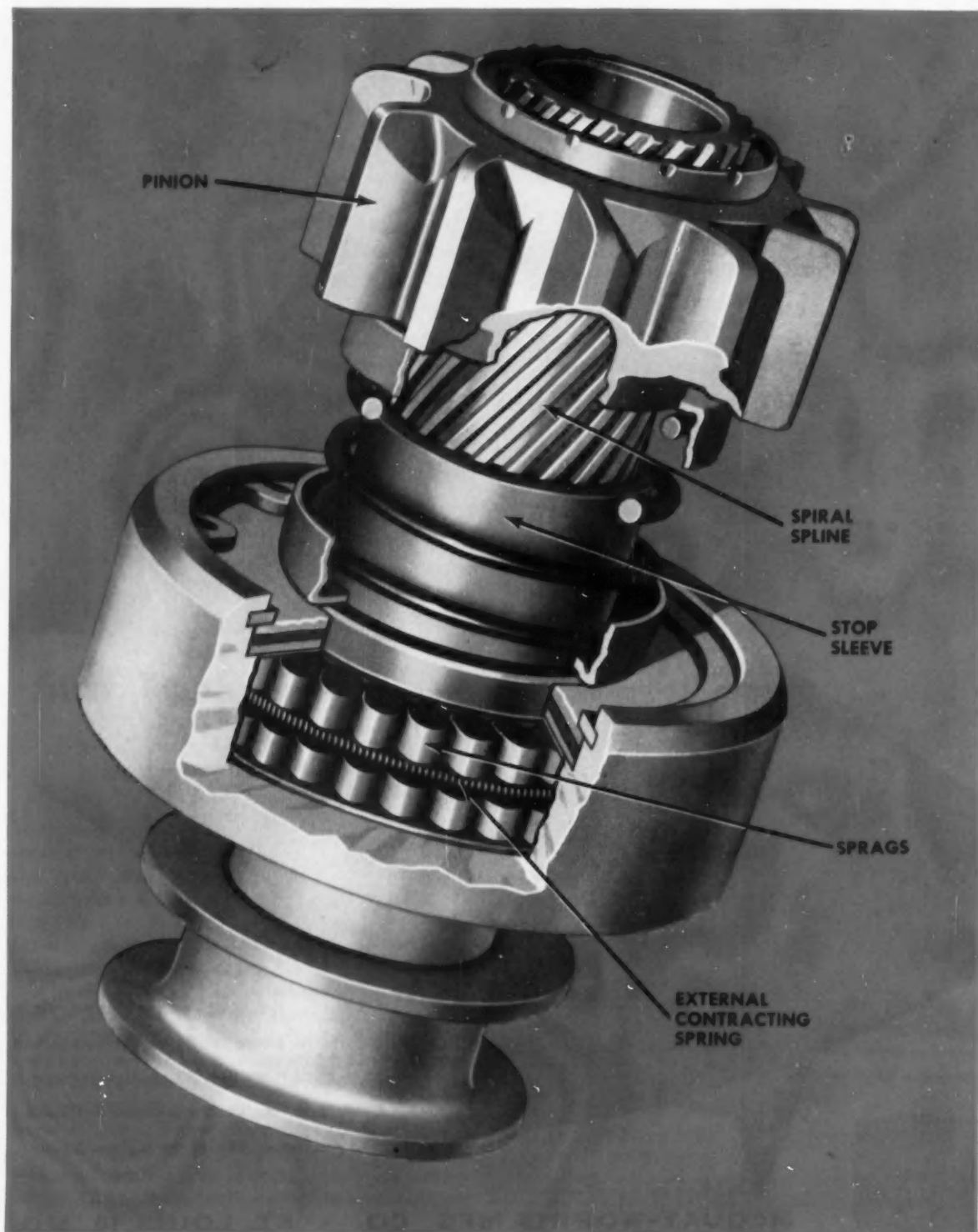
PISTON RINGS



Since 1910, McQuay-Norris
has played a leading role in
the piston ring field. This background
of more than 43 years experience is
available to manufacturers who require engineering
and production skills of the highest standard.

McQUAY-NORRIS MFG. CO. • ST. LOUIS 10, MO.

Progressive Engineering



Makes the Difference

DELCO-REMY'S NEW HEAVY-DUTY SPRAG CLUTCH HANDLES HIGHER TORQUE LOADS

Although no larger in size than earlier types of heavy-duty overrunning clutches, Delco-Remy's new *sprag* clutch has much higher torque capacity. Its remarkable increase in torque capacity is accomplished by a division of the load among 32 elements (sprags) rather than six rollers as in former overrunning clutches.

Other important mechanical features of the new clutch are . . . relative rotary motion between pinion and ring gear, provided by a spiral spline, which normally relieves tooth abutment on first attempts and insures starts on second attempts . . . stop sleeve which limits pinion travel to prevent "spinning meshes" if abutment is *not* relieved on first attempt . . . provision for *full* mesh engagement of pinion before cranking occurs to eliminate corner-of-tooth breakage and fatigue . . . low-friction overrun at high speeds provided by external contracting spring which automatically relieves tension on sprags under centrifugal force.

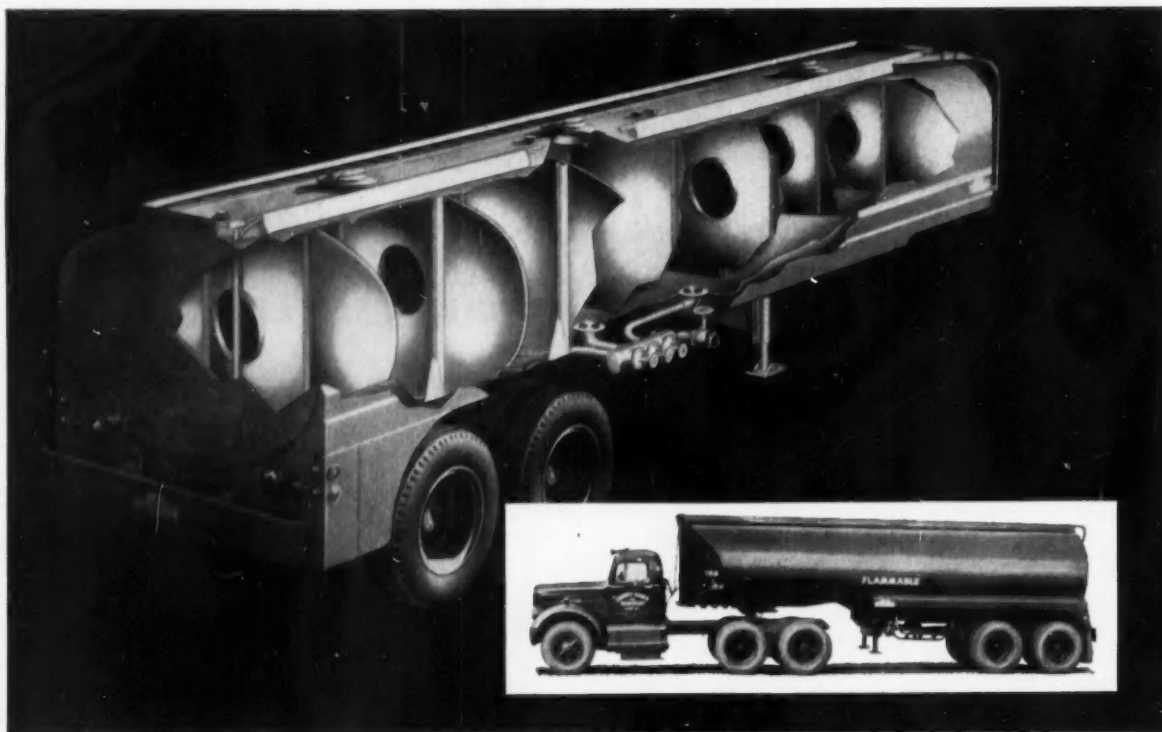
Specifically designed for cranking motor applications, this new sprag clutch is typical of Delco-Remy's willingness and ability to be ready when further advances in automotive electrical equipment are needed. This is Progressive Engineering at work.



Delco-Remy
ELECTRICAL SYSTEMS

DELCO-REMY • DIVISION OF GENERAL MOTORS • ANDERSON, INDIANA

Cutaway illustration of "trailerized" tank for petroleum trailer manufactured by The Heil Co., Milwaukee, Wis. and Hillside, N. J., and utilizing "Mayari R," a high strength, low alloy nickel steel produced by Bethlehem Steel Co., Bethlehem, Pa.



Users of Heil "trailerized" tankers find that every pound of deadweight trimmed off not only saves fuel, but also lessens wear on tires and brakes. This means lower operating cost and higher revenue per ton mile.

Nickel alloy helps designer eliminate trailer tank frame

Payload increased and deadweight cut by utilizing high strength, low alloy steel containing nickel

SIMPLIFIED DESIGN of this tanker eliminates not only the frame but also many supporting members ordinarily used in trailer tanks.

The manufacturer, The Heil Co., trims off 20 per cent in deadweight, yet increases the payload capacity of these units without sacrificing safety or increasing axle loading.

Capacity is safely increased by using tank shells, baffles, and deep-dished heads that have ample strength for the greater load because they are made of a high strength, low alloy steel containing nickel.

Heil uses a Bethlehem Steel Company product known as "Mayari R." Steels of this type in thin, light sections, provide the same strength and

safety as thicker, heavier sections of plain carbon steel. These steels also respond readily to fabrication, including welding and cold forming.

They give you other advantages, too. Their greater resistance to impact, wear and abrasion lengthens the life of structures subject to hard usage. And you get obvious benefits from the superior resistance they offer to atmospheric and many other types of corrosion.

Produced under a variety of trade names by leading steel companies, high strength, low alloy steels containing nickel along with other alloying elements are widely used in automotive and allied fields.

Investigate how you can cut needless weight, yet increase the payload capacity of your vehicles. Write us today for your copy of the publication "High-Strength Low-Alloy Steels."



THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street
New York 5, N. Y.

more dependable starting *under all operating conditions*

**"No Kick-Out" feature sets new standards
in starting performance.**

■ Since the earliest days of the automotive industry Bendix® Starter Drives have been noted for reliable starting.

Now with the new and latest Bendix Folo-Thru Starter Drive, starting, even under the most adverse weather conditions, has been improved immeasurably.

Although this new Bendix Starter Drive is fundamentally similar to its illustrious predecessors, it is specially designed to follow through the weak explosions until the engine actually runs on its own power.

That's why cars, trucks and buses equipped with the Bendix Folo-Thru Drive are easier and quicker to start under all operating conditions.

*REG. U.S. PAT. OFF.

ECLIPSE MACHINE DIVISION OF



ELMIRA, NEW YORK

Export Sales: Bendix International Division,
205 East 42nd St., New York 17, N. Y.



Bendix folo-thru starter drive

costs less—The new Folo-Thru Drive requires no actuating linkage and the less expensive solenoid may be placed in any convenient position. Results are lower installation costs and no adjustments. Complete detailed information is available on request.



Bendix® Folo-Thru Starter Drive



Bendix® Automotive Electric Fuel Pump

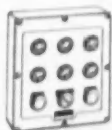


Stromberg® Carburetor





Time-saver, space-saver, money-saver ...Tinnerman tubular **SPEED CLIP**®!



Here's how the General Electric Company is keeping costs and space requirements low on its G-E oiltight Indicating Lights. They use Tinnerman tubular-type **SPEED CLIPS** to assemble the resistor to its support. This one-piece, spring-steel fastener reduces assembly time, material costs, parts handling and inventory by eliminating a long bolt, centering washer, lock washer and nut. It also reduces the dimension across the resistor support and saves valuable space when the lights are used close to pushbuttons and other components.

A wide variety of types and sizes of tubular-type **SPEED CLIPS** are used on everything from toys to autos—on metal, plastic or wood. They snap into punched or molded holes by hand; are self-retained in stud-receiving position. **SPEED CLIPS** are also ideal for blind attachments where only one side of an assembly is accessible.

Possibly Tinnerman **SPEED NUT** brand fasteners can help you improve your present fastening methods. See your Tinnerman representative soon and write for your copy of "SPEED NUT Savings Stories".

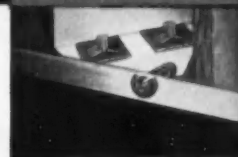
TINNERMAN PRODUCTS, INC. • BOX 6688, DEPT. 12, CLEVELAND 1, OHIO

Canada: Dominion Fasteners, Limited, Hamilton, Ontario. Great Britain: Simmonds Aero-accessories, Limited, Treforest, Wales. France: Aerocessaires Simmonds, S. A., 7 rue Henri Barbusse, Levallois (Seine). Germany: Hans Sicking GmbH "MECANO", Lemgo-Lippe.

TINNERMAN

Speed Nuts
FASTEST THING IN FASTENINGS®

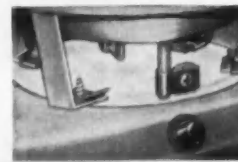
OTHER USES FOR **SPEED NUTS**



Tubular **SPEED CLIPS** save 51% in time, 34% in cost, assembling Drive-In auto speakers.



Push-On **SPEED NUTS** save 50% in assembly of rotating TV-antenna control box.



"J" and "U" type **SPEED NUTS** help gain 50% assembly saving on jet-convactor heater.



More than 8000 shapes and sizes

✓ **happy balance** between
dependable performance and moderate cost



ROLLWAY STEEL CAGE ROLLER BEARINGS

Tru-Rol *precision, steel-cage, heavy-duty bearing with contoured guide lips assuring true right-line rolling, maintained roller alignment and thin oil film.*

● Rollway's **TRU-ROL** Steel-Cage Bearings afford wide latitude in balancing *dependable* performance, *long life*, and *high load capacity* against *moderate* cost. They rate high in any comparison on a cost-performance basis.

A choice of stamped steel retainers with contoured guide lips, or steel segmented retainers assure true rolling and an evenly distributed *thin* oil film — *big factors in reducing power losses and heating.*

"Crowned" Rollers Relieve End Stress

TRU-ROL offers the extra advantage of a finish-ground "crown" radius on the roller ends. That relieves high end-stress and insures uniform load distribution over the entire length of the roller. The result: **TRU-ROL** Steel Cage Bearings carry heavier loads over longer periods without excessive end-fatigue. They are less affected by slight misalignment or shaft deflection.

Investigate **TRU-ROL** Steel Cage Roller Bearings before selecting any bearing in the medium price range.



TYPE D

Rollway Metric Series Steel Cage Roller Bearings

● Rollway Metric Series Steel-Cage Bearings offer the greater load capacity of solid cylindrical rollers, plus the true *right-line* rolling of *trunnion* rollers turning in a rigid steel cage. There's no roller skew, no pinch out, no cam action. Design permits maximum bearing capacity . . . within small space . . . at moderate cost.



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COMPLETE LINE OF RADIAL AND THRUST CYLINDRICAL ROLLER BEARINGS

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Please send a free copy of New Tru-Rol Catalog with extra Alignment Charts.

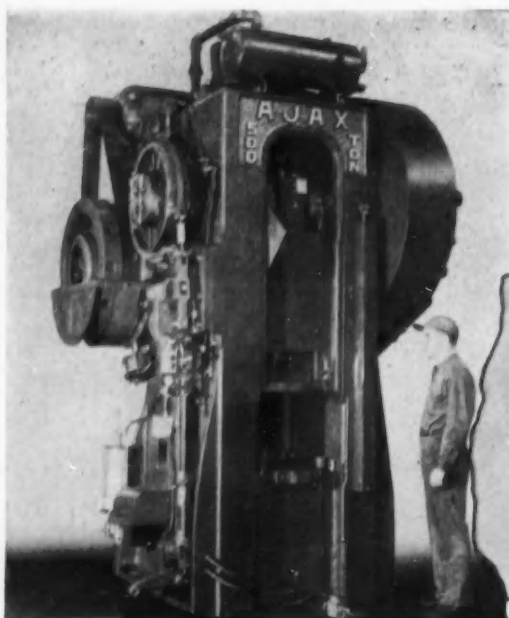
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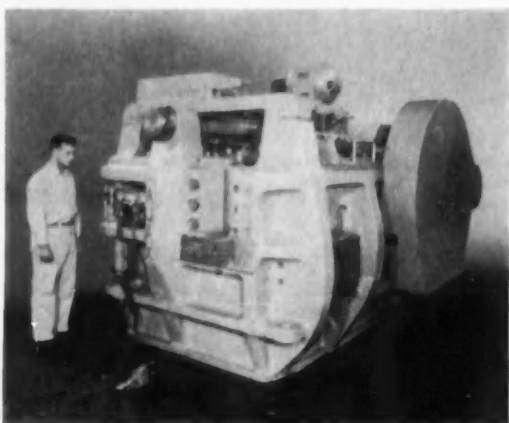
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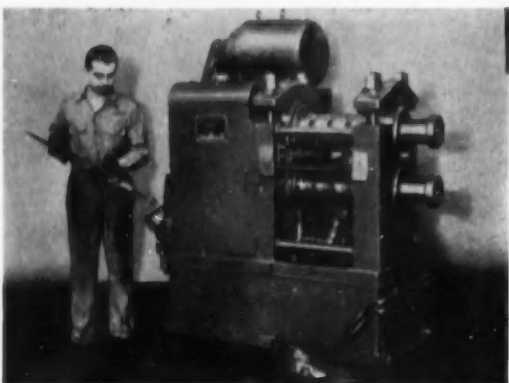
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AJAX 500 TON FORGING PRESS



AJAX 3" FORGING MACHINE —
with automatic transfer mechanism



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SAE JOURNAL, AUGUST, 1955



"I recommend

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Leather*

because style counts for a lot

when you're selling Oldsmobiles."

Mr. Raymond P. Scott
Oldsmobile, Wynewood, Pa.



"My customers take performance for granted when they're buying an Oldsmobile. What they are looking for is style and beauty. They get that—plus performance—when they choose one of the models upholstered in genuine leather. Leather is not only stronger, longer-lasting, and easier to care for—it is also the top of upholstery style."

Impartial tests back up what Mr. Scott says. Genuine leather upholstery is 77% stronger than the next-best upholstery material.

Only genuine leather wears as well as it looks.

YOU CAN GET THE FACTS THAT PROVE LEATHER IS BEST. Send the coupon today for "All About Genuine Leather" (free), showing results of tests by a famous impartial testing company.

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Please send me, free, your "All About Genuine Leather".

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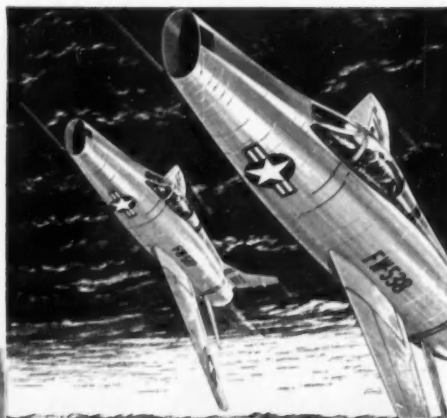
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Fast Filter Changes on the F-100 with Marman V-Band Coupling and Aeroquip Hose Lines



Here is an excellent example of how Marman clamps and Aeroquip hose lines work hand in hand to simplify aircraft plumbing installations:

On the North American F-100, a compact Marman stainless steel V-band coupling joins the fuel supply line to the filter. Utmost simplicity is achieved because the clamp flange has been machined right on the Aeroquip special hose fitting! The Marman "quick-coupler" latch adds quick assembly and disassembly advantages, and locks securely.

Marman clamps, straps, and couplings are used throughout the F-100 and many other planes for a wide variety of applications. Engineering assistance is available. Write for information.



MARMAN PRODUCTS COMPANY, INC.
A SUBSIDIARY OF **Aeroquip** CORPORATION

11214 EXPOSITION BLVD., LOS ANGELES, CALIFORNIA

MARMAN PRODUCTS ARE MANUFACTURED UNDER VARIOUS U.S. AND FOREIGN PATENTS AND OTHER PATENTS PENDING



*Judge
a Product
by
its Users*

In developing its versatile reconnaissance bomber, the RB-66, Douglas utilized a wide range of Aeroquip products and engineering services. The plumbing systems include Aeroquip weight-saving hose lines and, of particular note, rigid tubing assemblies made to precise specifications by Aeroquip.

 **Aeroquip**



Aeroquip Corporation, Jackson, Michigan • Aero-Coupling Corporation, Burbank, California (A subsidiary of Aeroquip Corporation)
Local Representatives in Principal Cities in U.S.A. and Abroad. Aeroquip Products are fully Protected by Patents in U.S.A. and Abroad.



The man who needs a new machine tool and doesn't buy it is paying for it anyway...

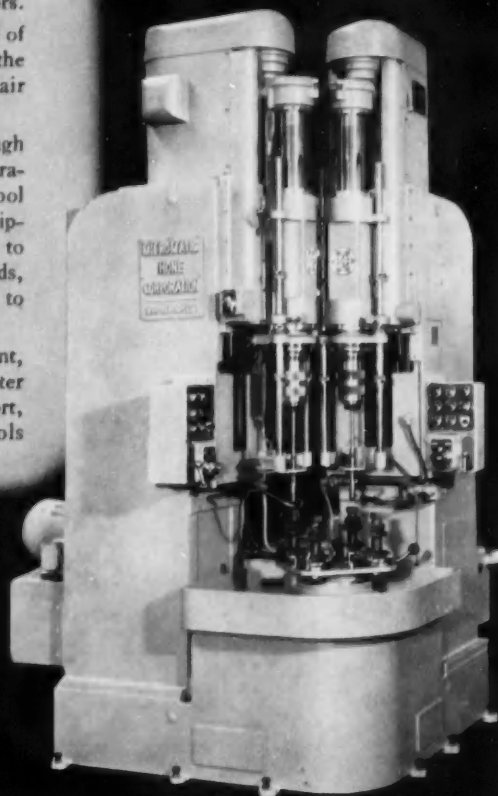
**in
high
maintenance
costs**

LOOK beyond the age of your equipment when considering whether maintenance costs indicate your need for new machine tools. The design of equipment and the method of processing used are equally important factors.

For example, fast spindle speeds and the necessity of maintaining perfect alignment between spindle and the fixture or chuck, call for frequent adjustment, repair and replacement of parts.

You can greatly reduce such maintenance costs through the Microhoning* process—which employs comparatively slow spindle speeds and self-alignment of tool and workpiece. And the design of Microhoning equipment makes easily accessible all components likely to require servicing... follows industry-accepted standards, such as the J.I.C. electrical and hydraulic codes, to provide greater safety to both operator and machine.

In reviewing your processing methods and equipment, you may discover your maintenance costs are greater than the price of new Microhoning equipment. In short, you may be paying right now for new machine tools you don't have.



PART:

Cluster gear—bore must be straight and concentric with gear teeth.

PROBLEM:

Excessive maintenance costs on fixture driver and chucks.

SOLUTION:

MICROHONING—Simple stationary fixture—self-aligning tools—straight bore concentric with gear teeth—increased production.

*MICROHONING = STOCK REMOVAL + GEOMETRY + SIZE CONTROL + SURFACE FINISH

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**THE
MACHINE TOOL
SHOW**

CHICAGO, ILL.
SEPT. 8-12, 1955



LOW COST WAY TO SEAL ROAD DIRT AND MOISTURE FROM AUTO BODY HOLES

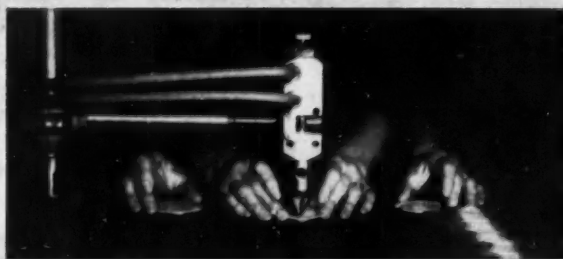
Suppliers to the automotive industry have found a way to save their customers thousands of costly man-hours in assembly, by using DAREX "Flowed-In" gaskets.

The problem was to seal body holes for auto trim against seepage of moisture and road dirt . . . and at the same time cut production time and costs. Dewey and Almy engineers recommended the addition of an integral gasket to the washer-nut fastener by the "Flowed-In" process, using DAREX "H637 Compound". This unique

fluid gasketing material flows on, cures in 20 seconds without shrinkage, and forms a perfect, rubbery seal that stays in place, is clean to handle and free from distortion.

The recommendation was adopted. The result: auto assembly lines are now fastening chrome trim with single unit fasteners . . . nut, washer and sealing gasket, all in one piece. Production is much faster . . . the finished job is neater, better and far less costly than before.

Interested? Mail coupon below for complete facts.



This illustration shows gaskets being flowed in place on a DAREX semi-automatic machine. The operator has only to feed with one hand, clear with the other. Automotive manufacturers are using machines like this one as well as high-speed, fully automatic DAREX equipment to gasket a wide variety of parts, including: washer-nut assemblies, covers for oil filters, air cleaners, oil pans, crankcases, transmission housings, overhead valve covers and shock absorbers.

Discover how DAREX "Flowed-In" gaskets can cut costs for you!

"H637 COMPOUND"

Base: Vinyl Sealing: Against water, dust, dirt Adhesion to metal: Excellent, no primer coat needed Torque retention: Excellent
Staining: No migration staining Temperature resistance: -20° to 250°F. Aging: Excellent Color: Gray
Consistency: (Wet) Non-slumping paste—(Dry) Rubbery Production rates: Semi-automatic—25 per minute; Automatic—150 per minute
Curing time: 20 seconds, no shrinkage Uses: Wherever integral nut, washer, gasket assemblies are used as a hermetic seal



DEWEY and ALMY
Chemical Company

DIVISION OF W. R. GRACE & CO.
Cambridge 40, Massachusetts

MAIL THE COUPON TODAY!

DEWEY and ALMY CHEMICAL COMPANY
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Please send me the new DAREX Flowed-in GASKET Brochure.

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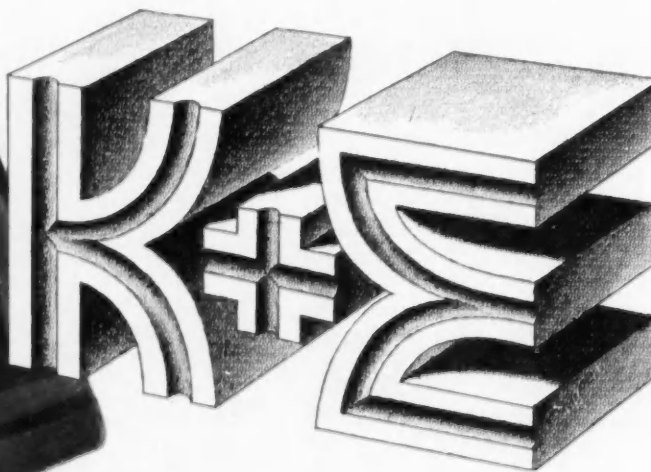
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Optical Tooling Equipment and Materials
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• Since 1867 engineers, scientists, designers, surveyors, draftsmen have relied on K&E as the foremost, most progressive, and most complete source of supply for the tools, equipment, and materials they work with. When you buy, think first of K&E, headquarters for 7,000 items. For example...

PARAGON® RED TIP RULING PEN

This is the only ruling pen with tungsten carbide points, so hard and durable that they hardly ever need sharpening—even after continued use on glass cloth, plastics and metals. Like the Paragon Red Tip Pen, all Paragon drawing instruments are outstanding—in durability, precision, balance and the many years of perfect satisfaction they give to draftsmen. That is why the Paragon name is the recognized "first" in fine drawing instruments.

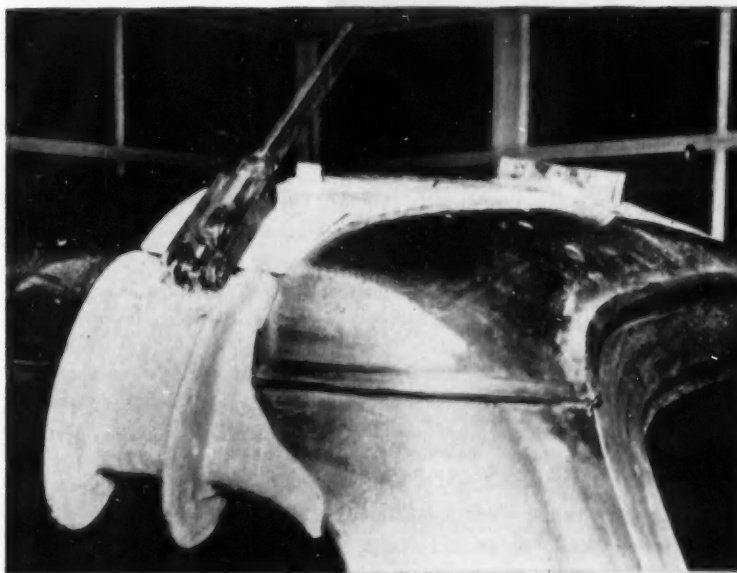


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Tooling time cut **50%**
with compounds based on
BAKELITE
TRADE-MARK
Epoxy Resins



REZOLIN Toolplastik Compound was cast against a finished body to form this spot welding jig. Time: only 21 hours compared with 45 to 80 needed to make one of conventional materials. Based on BAKELITE Epoxy Resin, this tooling compound is produced by Rezolin, Inc., Los Angeles 45, Calif.

Now metalworking tools can keep up with fast model changes. Less time, lower costs result because BAKELITE Brand Epoxy Resins offer these advantages:

- Liquid compounds—can be cast to shape without pressure
- Cured at room temperature—no applied heat
- Minimum shrinkage—minimum finishing
- Excellent flexural, compression, and impact strengths
- Outstanding dimensional stability
- Light weight means easy handling
- Laminated with glass cloth to form jigs, spotting racks, fixtures, and Keller models.

For further information, write Dept. JU-170



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In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario
The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC

LESS TORQUE

In leather—NATIONAL MICRO-TORC
TRADEMARK

Lowest torque • Highest lubricity • No measurable leakage
Runs cool, lasts longer • Sealing lip stores oil



Fig. 1. National Micro-Torc Oil Seal. Oil cannot pass through elastomer coated side. Inner body retains natural porosity for "oil storage".



Fig. 2. Leather seal completely impregnated with rubber. Natural porosity of leather is destroyed by intense impregnation.

Shaft Size	Break Away Torque		Running Torque	
	Conventional Leather	Micro-Torc	Conventional Leather	Micro-Torc
1.500"	39 oz-in	7 oz-in	60 oz-in	56 oz-in
2.937"	136	39	233	164
3.612"	95	49	287	207

Fig. 3. Breakaway and running torque measurements, National Micro-Torc vs. conventional leather oil seals.

Test Conditions	NMB Micro-Torc		Completely Impregnated Leather Seal	
	C-1042	C-1043	D-100	D-101
Shaft Speed:	2300 RPM		800 RPM	
Shaft Size:	3.675"		2.750"	
Shaft Runout, YIR:	.003"		.004"	
Oil Temperature:	200° F.		165° F.	
Test No.	C-1042	C-1043	D-100	D-101
Total Running Time:	1017 hrs.	1017 hrs.	108 hrs.	108 hrs.
Condition after Test:				
Sealing Member:	Flexible	Flexible	Very Stiff	Very Stiff
180° Bend Test:	Surface Cracks	Surface Cracks	Deep Cracks	Deep Cracks

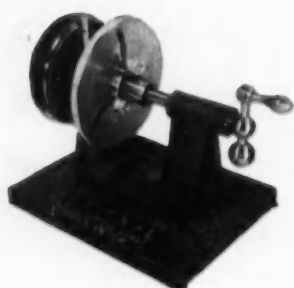
Fig. 4. Service life test results. National Micro-Torc Oil Seals vs. completely impregnated leather seals.

Revolutionary new Micro-Torc Oil Seals, exclusively from National, employ a leather sealing member coated on the surface with a high lubricity elastomer. This coating not only reduces torque as much as 80% but effectively prevents lubricant leakage. Since the coating is applied to the outer surface of the sealing member only, the body of the sealing lip retains its natural porosity to store oil for periods of semi-starved operation. (Figure 1.)

The appreciable superiority of Micro-Torc over completely impregnated leather seals (Figure 2) is shown at left. In addition to a marked reduction in torque (Figure 3), service life of Micro-Torc seals was test-proven to be up to 10 times the life of completely impregnated seals, and 2 to 3 times that of wax or resin impregnated seals. (Figure 4.)

In dry-running life tests Micro-Torc seals operated for 100 hours at 1,350 rpm *with no lubrication*. No squealing or sloughing was experienced, and all Micro-Torc seals remained flexible and operative.

National Micro-Torc Oil Seals are recommended for application where temperatures do not exceed 200° F, shaft speeds are not over 2,000 fpm and runout is not greater than .010 indicator reading. For minimum torque, cool operation and long life in leather oil seals, specify National Micro-Torc. Write or telephone nearest National Applications Engineer for complete information.



New! NATIONAL TORQUE METERS

New National Torque Meters provide a simple, accurate way to measure torque of oil seals. The meters are rugged, compact, easily portable, ideal for production line or receiving department. They have an easy-acting self-centering chuck for accurate seal holding, and use a simple taper-fitting test shaft you can make up in a matter of minutes. The Meters are designed for utmost simplicity, and with them unskilled personnel can make accurate torque readings with but a few moments training.

Two sizes: Model 615 fits seals up to 6" dia.; 15 lb. in. torque. Model 845 fits seals up to 8" dia.; 60 lb. in. torque.

Meters measure approximately 13" long x 10" wide x 11" high, weigh about 27 lbs. Sturdy carrying case can be furnished.

with NATIONAL OIL SEALS

In synthetic rubber—SYNTECH[®]

Low torque • Rubber-covered or ground O. D. • Long life
Zero leakage • Unaffected by most industrial fluids

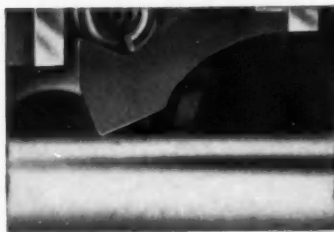


Fig. 5. Cross-section, typical National Syntech sealing lip. Note limited point of contact between seal and shaft.

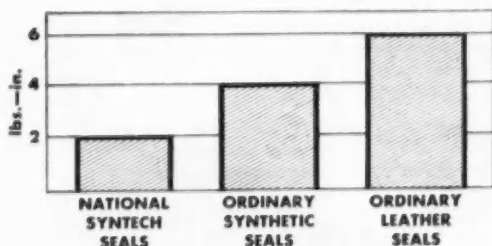


Fig. 6. Torque, Syntech vs. conventional synthetic rubber and leather oil seals. Seals tested on same shaft, under identical conditions.



Fig. 7. (Left) National Syntech Rubber-Covered O.D. (Right) National Syntech with machine-ground steel O.D.



Developed and introduced by National in 1946, National Syntech seals are among today's most widely used synthetic rubber oil seals. Their performance and dependability have been proven in thousands of commercial applications.

Syntech seals are particularly designed for higher speed, higher temperature applications where torque must be held to the absolute minimum. They feature an exclusive sealing lip design (Figure 5) which insures minimum contact between lip and shaft, yet provides zero leakage over a long service life. The marked difference in torque between Syntech and ordinary leather seals can be as much as 200%, as shown in Figure 6.

National Syntech Oil Seals are available in a wide selection of types and sizes, including seals with rubber covered or machine-ground peripheries (Figure 7) spring-tensioned or spring-less, or with twin or triple lips for special applications.

Call in a National Applications Engineer

CHICAGO, ILL. . . . Room 4113 Field Building, FRanklin 2-2847
CLEVELAND, OHIO . . . 210 Heights Rockefeller Bldg., YELlowstone 2-2720
DALLAS, TEXAS . . . 30½ Highland Park Village, JUstin 8-8453
DETROIT, MICH. . . . 726 Lothrop Avenue, TRinity 1-6363
DOWNEY (Los Angeles Co.), CALIF. . . 11634 Patten Rd., TOpas 2-8166
INDIANAPOLIS, INDIANA . . . 2802 North Delaware St., WALnut 3-1535
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REDWOOD CITY, CALIF. . . . Broadway and National, EMerson 6-3861
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MORE INFORMATION?

NATIONAL MOTOR BEARING CO., INC. DEPT. C, REDWOOD CITY, CALIFORNIA

Please send complete information, illustrated technical details on
Micro-Torx seals _____ Syntech seals _____ Torque Meter

Name _____
Company _____
Street _____
City _____ Zone _____ State _____

DD16

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Diesel fuel additive to relieve filter-plugging and injector-sticking problems

In an effort to reduce operating costs, the railroads have recently done considerable work with catalytic-cracked and blends of cat-cracked and straight-run diesel fuels.

Engine performance problems

With the cooperation of the refiners, much progress has been made by the railroads in the efficient use of these fuels. However, there are a number of problems inherent in such a change of fuels—some of them having a direct bearing on the performance of diesel engines.

Filter-plugging—which is likely to result in injector-sticking—has been one of these problems.

To solve it, many refiners are now us-

ing a Du Pont additive, FOA-2, to stabilize cracked distillates and overcome incompatibility between blends of cracked and straight-run stocks. Many of the leading railroads are reporting excellent results with No. 2 fuel oils containing FOA-2.

Good filterability

Du Pont FOA-2 is a dispersant as well as a stabilizer. And because of its excellent dispersant action, it improves the filterability of diesel fuels. In this way, it helps to eliminate most injector-sticking and filter-plugging problems.

In addition, being an ashless, non-metallic additive, Du Pont FOA-2 does not contribute to the exhaust stack spark-

ing problem. It is economical, too, since it is effective in low concentrations.

Developing new additives for improved fuel and lubricant performance is a continuing project of the Du Pont Petroleum Laboratory. For more complete information on Du Pont FOA-2 and other new Du Pont additives, address your request to any of our regional offices listed below.



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Petroleum Chemicals Division • Wilmington 98, Delaware

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IN CANADA: Du Pont Company of Canada Limited—Petroleum Chemicals Division—80 Richmond Street West, Toronto 1, Ontario
OTHER COUNTRIES: Petroleum Chemicals Export—Nemours Bldg., 6539 Wilmington 98, Delaware

46 Major Projects at Lockheed

Advance Careers of Engineers

Lockheed projects cover virtually the entire spectrum of aeronautical engineering endeavor, including turbo-prop, turbo-compound and jet transports; jet fighters, trainers and bombers; vertical rising aircraft; nuclear applications to aircraft and many other significant classified activities.

It is the largest development and production program in the company's history, with 13 models already on assembly lines.

Diversification such as this offers engineers:

- More opportunity for promotion—because there are more high echelon positions to be filled on such a large number of projects.
- More career security—because Lockheed activities span so many phases of aeronautical effort.
- More stimulating work—because there is a wider range of assignments, because engineers have more scope for their ability, because a firm active on so many fronts of aviation welcomes and rewards fresh thinking, new ideas.

To engineers who lack aircraft experience:

Aircraft experience is not necessary to join Lockheed. It's your engineering degree and engineering experience that count. Lockheed adapts your training and ability to aircraft work through its Engineering Transitional Program. Naturally, you receive full pay during the Transitional Program.

Generous travel and moving allowances enable you and your family to join Lockheed at virtually no expense to yourself. Lockheed Employee Service helps you get settled when you arrive.

Immediate Openings for: AERODYNAMICS ENGINEERS • AIRBORNE ANTENNA RESEARCH ENGINEERS • DESIGN ENGINEERS — at all levels in mechanical, electrical, hydraulic, power plant, controls and structures fields. • FLIGHT TEST ANALYSIS ENGINEERS • MATH ANALYSTS — to work on Lockheed's two 701 Digital Computers MICRO-WAVE SPECIALISTS—with at least three years' direct experience in an advisory capacity on airborne radar applications as well as a broad theoretical background and an advanced degree in Electronics or Physics • OPERATIONS RESEARCH SCIENTISTS • STRESS AND STRUCTURES ENGINEERS • STRUCTURES RESEARCH ENGINEERS • THERMODYNAMICS ENGINEERS • WEIGHT ENGINEERS.

A report on "High Heat Treat Steel" taken from one of Lockheed's monthly engineering and manufacturing forums is available to interested engineers. Address requests to the forum chairman, E. H. Spaulding.

Engineers interested in Lockheed's expanding development and production program are invited to write to E. W. Des Lauriers, Dept. MP-16-8.

Below: Lockheed engineers at work on various projects



Operations Research study on overseas transport routes



Aerodynamic meeting on high-speed fighter



Fatigue test on Super Constellation skin



Antenna pattern study on radar search plane



Design study on hydraulic requirements of new transport

Lockheed

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Midland's air Hy-Power unit, which assures you ample braking capacity at all times, is available in kits for tractors, trucks, and buses through Midland's nation-wide distributor organization.

Each Midland power brake kit is especially engineered for a specific tractor, truck, or bus — and each working part has been subjected to the most rigid tests to guarantee its meeting Midland's high standards of quality.

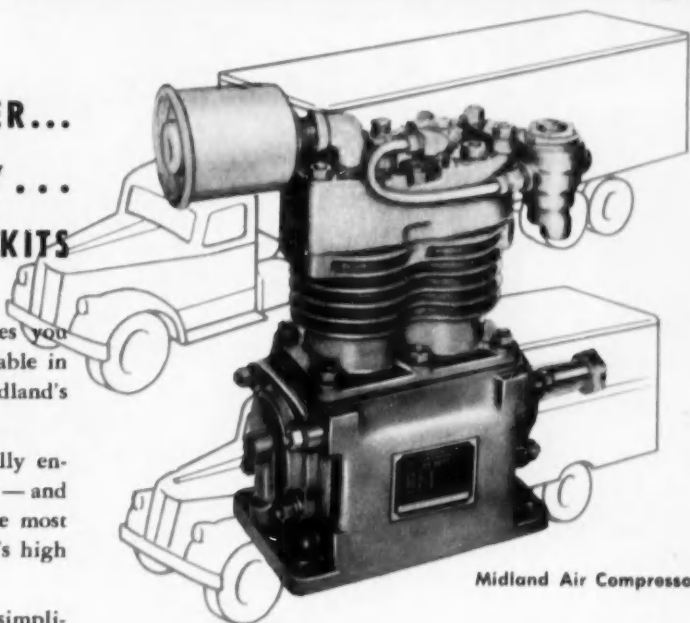
Midland's air Hy-Power unit is the most simplified, most effective, most up-to-date of air-over-hydraulic systems. Its fewer parts, lighter weight, and direct applied power make it the number one safety and economy buy for you.

The Midland Compressor is known throughout the truck and bus industries for its greater efficiency, cooler operation, simpler installation. Provides ample reserve braking power for the worst traffic emergencies.

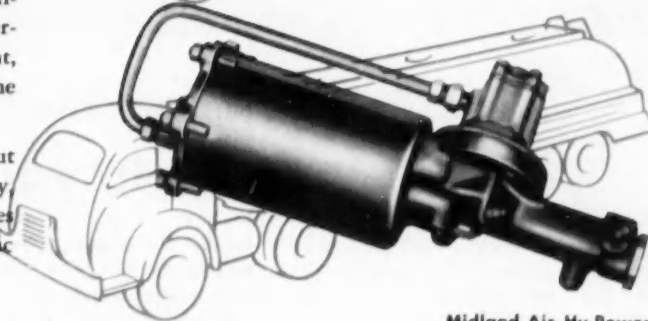
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Midland Air Compressor

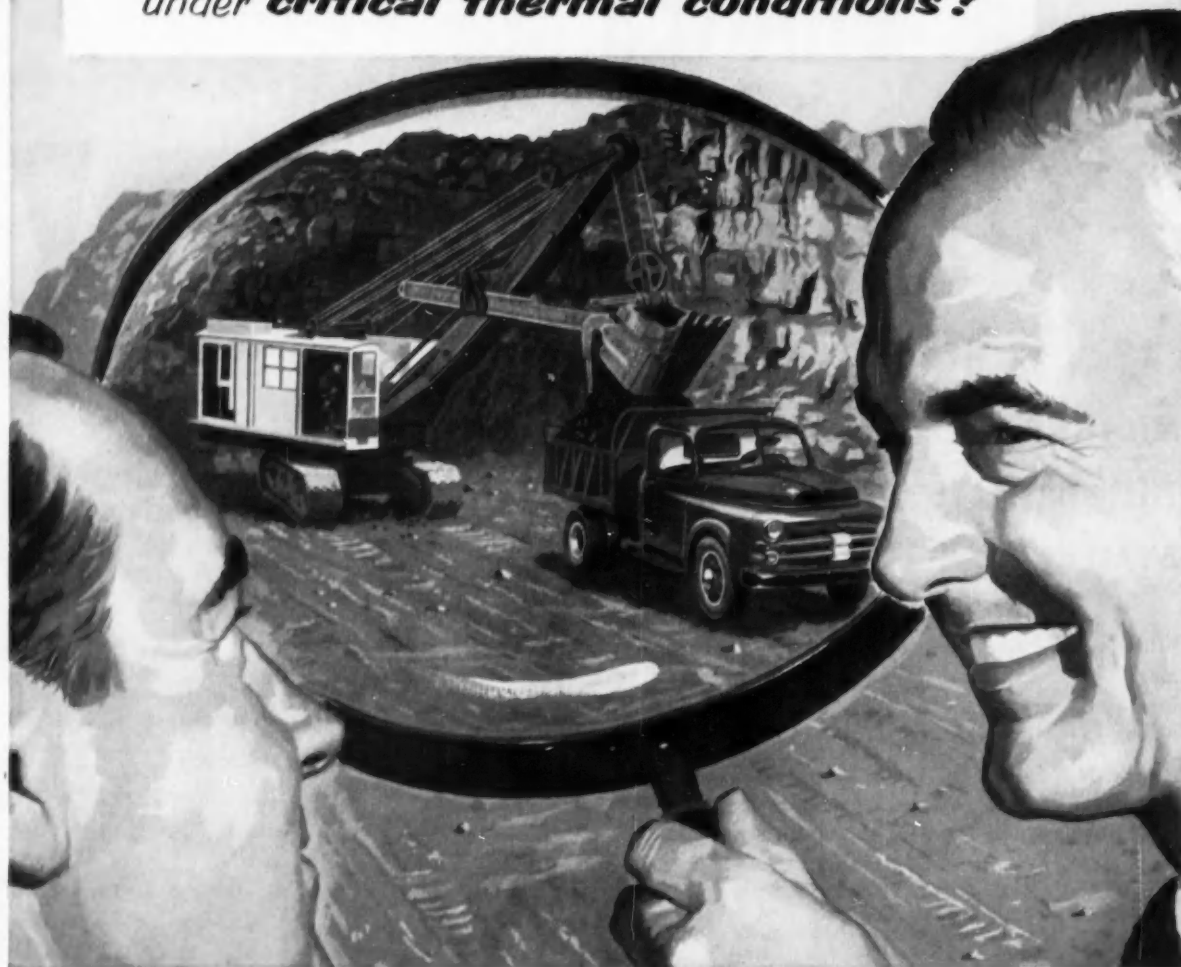


Midland Air Hy-Power



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Power Brakes Choose
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*Need a friction material to stand up
under **critical thermal conditions?***



The J-M Friction Materials Specialist can help you find it

WHEN YOU'RE FACED with a problem calling for a friction material for use under extreme thermal conditions, ask the J-M specialist to help you. He can offer a wide choice of friction materials that have proved their ability to perform efficiently at operating temperatures up to 750° or more.

Available in low, medium and high

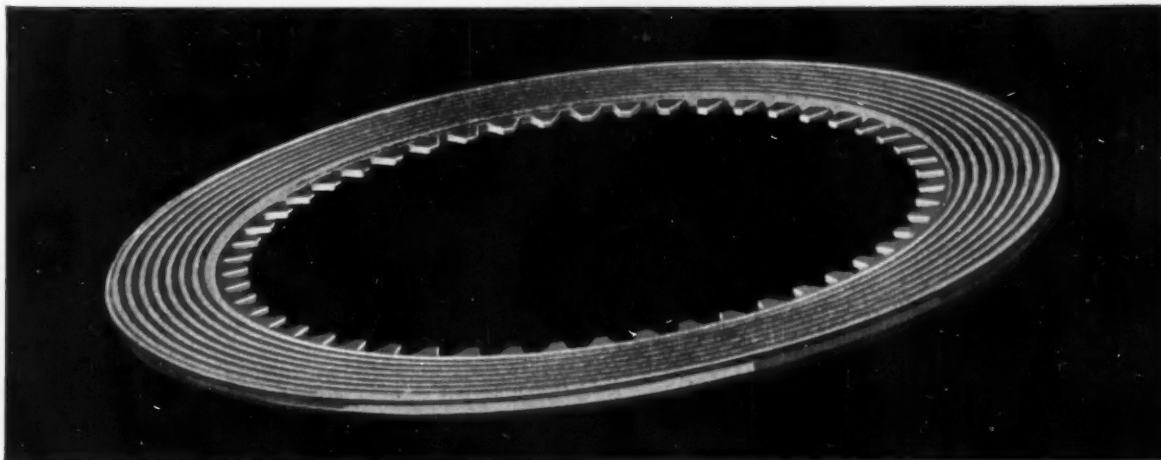
friction coefficients, these linings and facings are specially engineered to withstand severe shock, maintain friction stability under critical temperatures, provide smooth action at a low rate of wear. If your requirements demand a friction material that must be custom-made for a special use . . . the Johns-Manville Research facilities are available to help develop that

just right formulation.

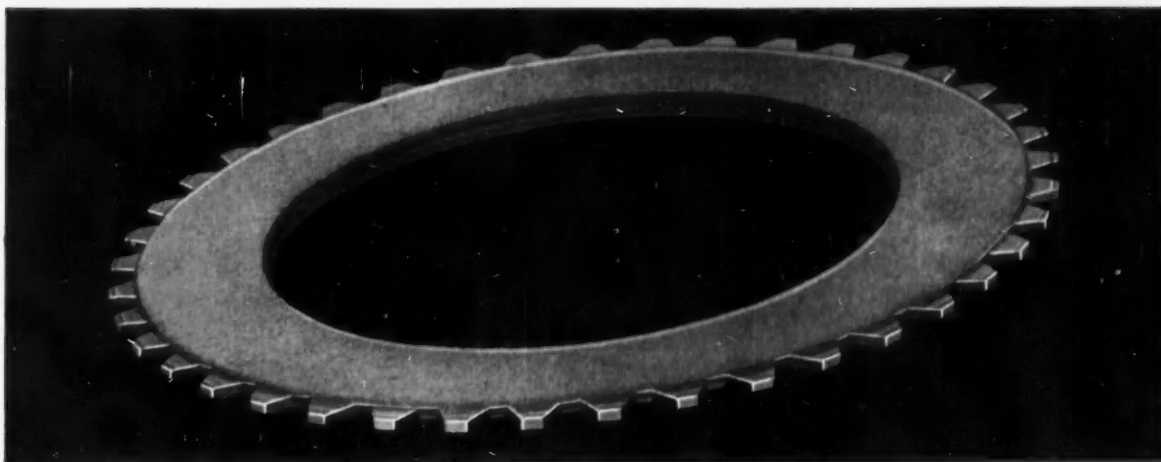
Whatever your friction material problem, the J-M Friction Materials Specialist is at your service. Or, write for reference booklet FM-12A that contains a complete description of J-M Friction Materials and a handy selector chart. Address Johns-Manville, Box 60, New York 16, N. Y. In Canada, Port Credit, Ontario.



Johns-Manville INDUSTRIAL FRICTION MATERIALS



Clutch plates for modern automatic transmissions incorporate semi-metallic facings (above) or non-metallic facings, according to manufacturer's specifications.



OFFER IMPORTANT ADVANTAGES IN

many applications...

moraine friction materials

Moraine all-metallic, semi-metallic, and non-metallic friction materials resist heat, wear and corrosion in a wide variety of applications. And it's *how well* and for *how long* they do these things that makes Moraine friction materials so superior. They've proved their stable frictional properties in Powerglide, Hydramatic, and Dynaflo automatic transmissions. Now they're being used in heavy-duty truck transmissions, in special military vehicles and equipment, in automotive air conditioning, and

in household appliances. If you have a problem involving the automatic transmission of power, Moraine's experience and ability with friction materials may be of value to you.

Other Moraine products include: Moraine-400 bearings, toughest automotive engine bearings ever made—M-100 engine bearings and Moraine conventional bi-metal engine bearings—Self-lubricating bearings—Moraine friction materials—Moraine metal powder parts—Moraine porous metal parts—Moraine rolled bronze and bi-metal bushings—Moraine power brakes—Delco hydraulic brake fluids, Delco brake assemblies, master cylinders, wheel cylinders and parts.



**moraine
products**

DIVISION OF GENERAL MOTORS, DAYTON, OHIO



**"Wagner Air Brakes have averaged
200,000 miles of service without
any major compressor
maintenance cost."***

* Says: **WALTER SAYLES**, Superintendent of Maintenance
MORRISON MOTOR FREIGHT, Inc., Akron, Ohio

It's a matter of record, from hundreds of case histories, that **WAGNER AIR BRAKES** render the reliable safety-proven performance fleet operators demand. This dependability is the result of more than thirty years' experience in manufacturing brakes and complete brake systems. The advantages of **WAGNER AIR BRAKES** gained by Walter Sayles of Morrison Motor Freight, Inc., are indicative of this outstanding record.

WAGNER AIR BRAKE SYSTEMS are available either as "straight air" or "air-over-hydraulic," and all feature the **WAGNER ROTARY AIR COMPRESSOR**. Learn for yourself why more and more safety-minded, cost-conscious fleet operators are specifying **WAGNER AIR**.

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Send for your free copy of Wagner Bulletin KU-201 for full information and complete details. It will be sent to you without cost or obligation. Mail your request, today.

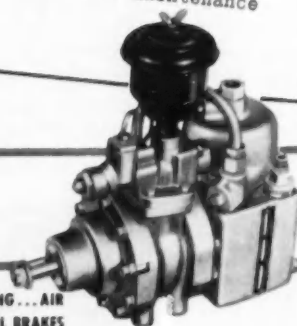
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BRAKES... TACHOGRAPHS... ELECTRIC MOTORS... TRANSFORMERS... INDUSTRIAL BRAKES



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GENERAL OFFICES • 1102 EAST JENNINGS BLVD. • AKRON 6, OHIO

Wagner Electric Corporation
6400 Plymouth Avenue
Saint Louis 14, Missouri

Gentlemen:

To insure top quality hauling service throughout Ohio, Indiana, Illinois, Missouri and Kansas, we are very safety minded and insist that all our road units have good dependable air brakes. We feel that this responsibility is of utmost importance if a common carrier is to safeguard customer's cargo.

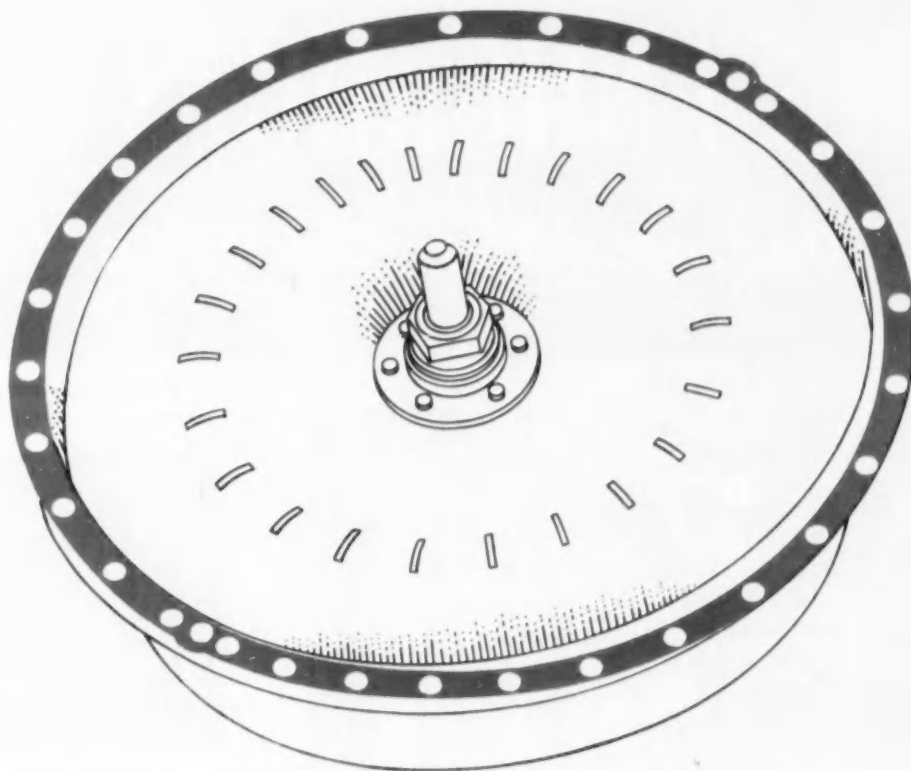
About 90% of our tractors have Wagner Air Brakes and it has been my experience, as Superintendent of Maintenance, that your Rotary Air Compressors have done an excellent job for us in the past 3 years. Wagner Air Brakes have averaged 200,000 miles of service without any major compressor maintenance cost. We also appreciate the quiet operation of the compressors.

Sincerely,

Walter Sayles

Walter Sayles
Superintendent of Maintenance





Neoprene-treated paper cuts torus-cover-gasket cost 50%

Sealing the torus cover on the transmission of a leading 1955 passenger car was one problem that didn't bother the engineers. For this was the third year they'd called on a new type of paper—a paper treated with neoprene, Du Pont's chemical rubber—to do this critical job. They *knew* they could depend on it.

Previous materials required "kid-glove" treatment. They were sensitive to moisture—would expand or shrink from day to day. And bolt torque requirements were high, leaving little margin for variation in heat treating the bolts. The new neoprene-treated paper provided the solution. It had excellent dimensional stability and re-

quired 20-25% less torque. In service, it sealed perfectly against the hot transmission oil. And the neoprene-treated paper cost 50% less than former materials!

Neoprene earns its way in the automotive field by outperforming other resilient materials on the most exacting jobs. Automobile designers know they can count on neoprene products for *extra-long* service that builds customer confidence and satisfaction.

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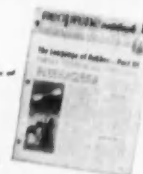
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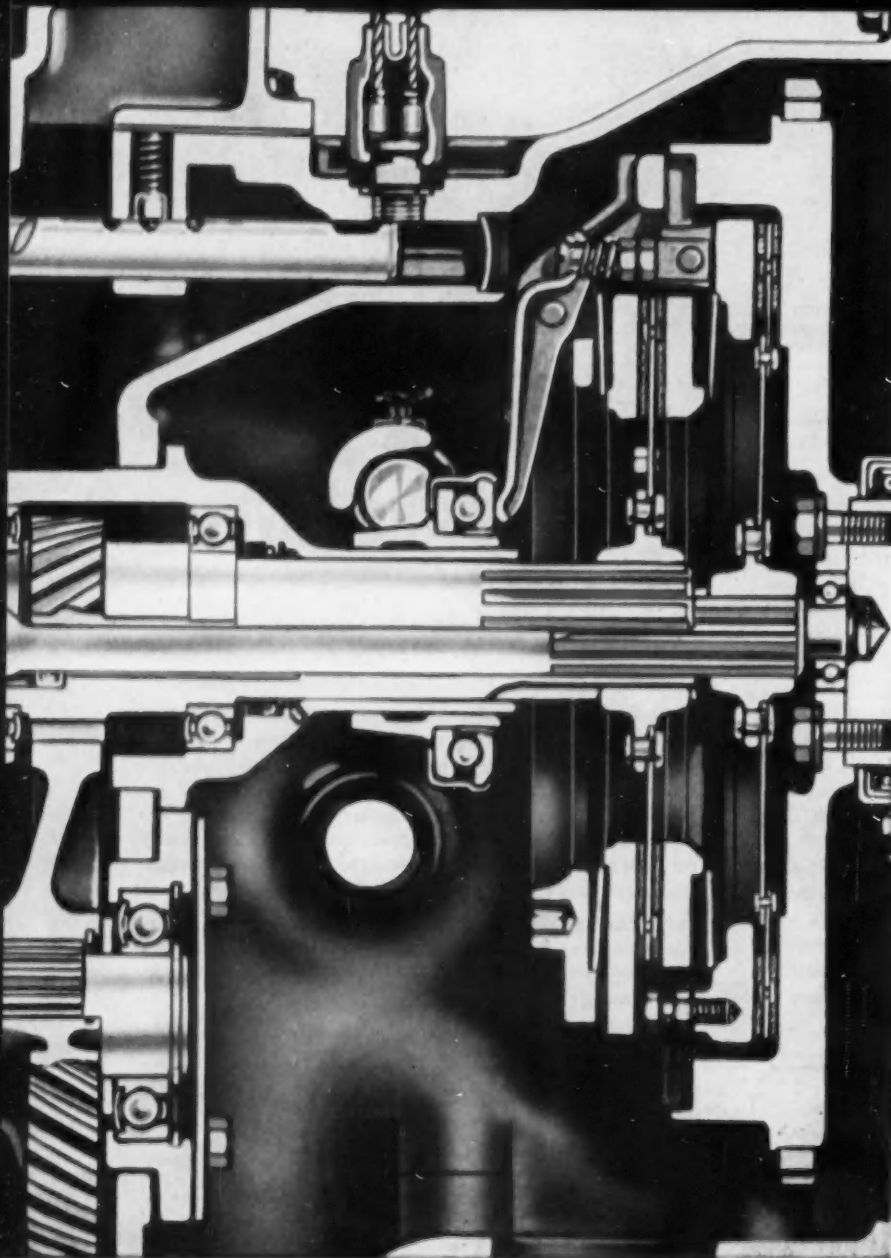
The rubber made by Du Pont since 1932



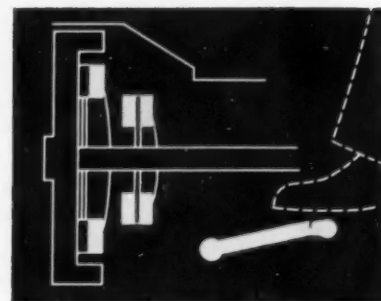
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DANA ANNOUNCES NEW

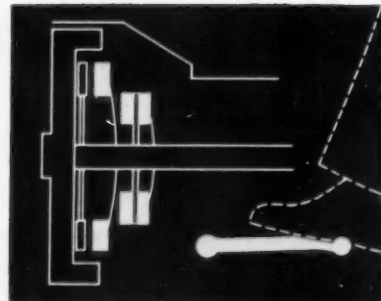
Gives Operator ONE-PEDAL Control of



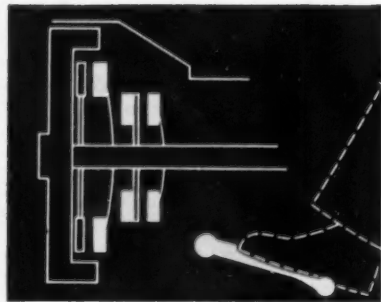
The "2-Stage Clutch with the Built-In Feel" designed by Spicer for the Ferguson 35



1. Both transmission and power take-off are fully engaged when clutch pedal is up.



2. Pedal half way down disengages transmission only. PTO continues to operate.



3. Pedal all the way down disengages both transmission and PTO.

DANA CORPORATION • TOLEDO 1, OHIO

Spicer

TRACTOR CLUTCH

Both Transmission and Power Take-Off!

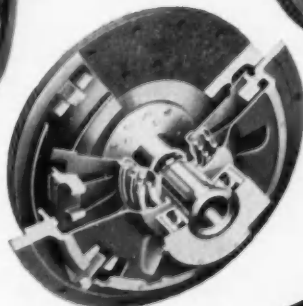
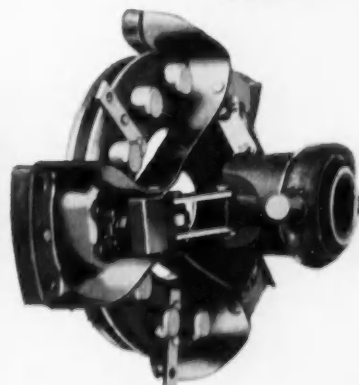
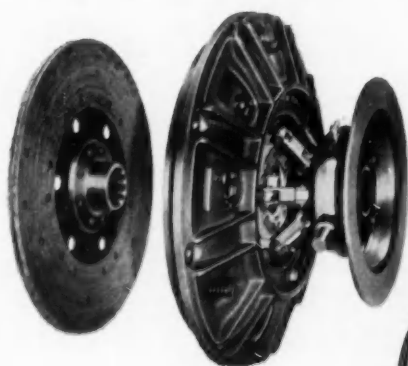
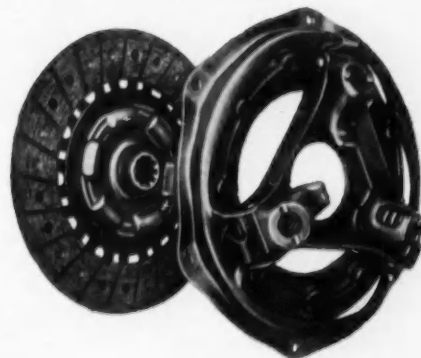
This new Spicer Clutch . . . developed by Dana engineers for the Ferguson 35 Tractor . . . assures farmers of increased safety and efficiency. They can operate such machines as the baler, mower, corn picker, forage harvester continuously regardless of tractor starts and stops.

Since the left foot of the operator gives complete control over *both* tractor motion and PTO, both hands are entirely free for steering, gear changes, and other driving requirements. See details of clutch mechanism and operation at left.

This new 2-Stage Clutch is another engineering advancement made possible by the wealth of Spicer experience in power transmission problems, and by research and development facilities unexcelled in the industry.

The Dana Corporation offers clutches of many types for automotive, tractor and industrial power transmission needs. These clutches embody advancements and exclusive features that assure outstanding performance in the field.

Ask Spicer engineers to help solve your particular power transmission problems.



Spicer

SPICER PRODUCTS: TRANSMISSIONS • UNIVERSAL JOINTS • PROPELLER SHAFTS • AXLES • TORQUE CONVERTERS • GEAR BOXES • POWER TAKE-OFFS • POWER TAKE-OFF JOINTS • RAIL CAR DRIVES • RAILWAY GENERATOR DRIVES • STAMPINGS • SPICER AND AUBURN CLUTCHES • PARISH FRAMES

FOR FASTER ACCELERATION, LOWER FUEL CONSUMPTION, WITH THE SAME AXLE RATIO

It's an engineering fact that a 10% change in car weight has the effect on acceleration of a .4 change in the numerical rear axle gear ratio.

A decrease in weight is the one sure means of obtain-

ing faster acceleration and lower fuel consumption without changing axle ratio.

For example, a 10% decrease means a proportionate reduction in fuel consumption.

...think of *Kaiser Aluminum*

FOR CARS that are far lighter in weight—and have equal or superior strength to cars built with heavier ferrous or copper base metals—specify parts made with Kaiser Aluminum.

Many tested and proved parts made with Kaiser Aluminum—like those shown below now in use—are available today to give you the important benefits of lighter weight.


Aluminum parts give superior performance and service through aluminum's unique combination of properties, including light weight with strength, corrosion resistance, heat conductivity, light and heat reflectivity.

Initial costs are generally less, because *lightweight*

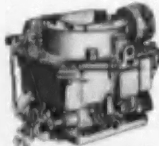
aluminum gives you up to *three times* more metal per pound. In production, the workability of aluminum makes it easy and economical to stretch, roll, cast, draw, forge, spin, stamp, extrude, or machine.

As America's fastest growing major producer of aluminum, we are ideally equipped to work with you. Our Product Development and Research Services can give you valuable assistance in designing aluminum automotive parts. A Kaiser Aluminum engineer will be glad to work with you immediately. Contact Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office*, Palmolive Building, Chicago 11, Illinois. *Executive Office*, Kaiser Building, Oakland 12, California.


These aluminum automotive parts have been proved superior
—and there are more on the way!




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Battery Cable

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Takes roughest punishment— **CLARK** Planetary Wheel Axle

Here is good engineering:
a double-reduction axle with
secondary reduction as near point
of tractive effort as possible—in the
driving wheel hub . . . Axle shaft wind-up
and torque load on all power-train
gears are greatly reduced . . . This axle
is also available as a steering-drive axle.
Steering linkage is rugged, dependable . . .
It's another conspicuous proof that
it's good business to do business with Clark



CLARK EQUIPMENT COMPANY • BUCHANAN • Battle Creek, Jackson and Benton Harbor, Michigan

CLARK®
EQUIPMENT



Ross Carrier takes tote boxes of castings to heat treat

How The Shoemaker's Children Got Shoes, or How we followed our own advice **AND SAVED \$6000 A YEAR!**

We recently put a Clark-Ross Carrier to work at our own Axle and Housing Division (Buchanan, Michigan) and saved ourselves \$6000 a year. Here's the background:

Our Buchanan plant is an integrated manufacturing operation, but it's spread out over a large area. Long ago we established a central transportation area to integrate the flow of materials to the outlying departments—foundry, shaft, wheel, heat treat, etc. All parts and assemblies are put in tote boxes or palletized for storage in the central area until they are needed in manufacturing or shipping. Previously all the materials were shuttled around to the various departments on a trailer-train. A tractor and driver, a flagman and 28

trailers were required for the job. It was slow, costly in terms of manpower and trailer maintenance, and often caused damage to the loads.

Then we put the Series 70 Carrier (10,000 lbs. capacity) to work. It eliminated the whole trailer-train, which had cost us \$2800 a year in maintenance. It eliminated the need for a brakeman—the Carrier is strictly a *one-man operation*. Its big pneumatic tires cushion the load, have eliminated virtually all damage to in-transit materials. At 25 mph, it runs rings around the old system, handles some 3,333,000 lbs. of material per 20-day work month.


Why not look up the name of your local Clark dealer in the Yellow Pages and ask him about the unique advantages of a carrier-handling system: one-man operated, self-loading (3 seconds), capacities up to 50,000 lbs., travel speeds to 56 mph. Speaking from personal experience, we recommend the Clark-Ross Carrier highly!

The Carrier replaced these and other trailers



**CLARK
EQUIPMENT**

ROSS CARRIER LINE
Industrial Truck Division
**CLARK EQUIPMENT
COMPANY**
Benton Harbor, Michigan



WHEN
YOU THINK
OF
**SEALING
RINGS**

REMEMBER . . .

Sealed Power

**MAKES
MOST
OF
THEM !**

THAT'S RIGHT !

Since automatic transmissions came into use, Sealed Power has made over 80,000,000 transmission sealing rings. It all began before World War II with sealing rings for tanks. Now we make them for passenger cars, trucks, and buses, as well.

There are 19 makes of cars now using automatic transmissions. 16 of these use Sealed Power sealing rings.

Sealed Power sealing rings are the product of 17 years of research and testing. They range from one inch to 14 inches in diameter.

They must seal oil pressure and they must be easy to install. Whatever your own sealing ring problem, Sealed Power is best qualified to help you. Write to us!

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Sealed Power Piston Rings
PISTONS • CYLINDER SLEEVES

Leading Manufacturer of Automotive and Industrial Piston Rings since 1911
Largest Producer of Sealing Rings for Automatic Transmissions • Power Steering Units

TAILORED POWER



FLEXIBLE POWER is the key to profitable hauling today. A vehicle must have the *workhorse pulling power* to haul heavy loads! *Torque* is needed for bad road conditions or hill-climbing! *Speed* is needed for fast hauling, to bring an empty vehicle back for new loads sooner.

TDA 2-Speed Axles answer trucking's need for flexible power. Exclusive double-reduction design permits a range of spreads all the way from 28% to 49% . . . in an almost unlimited number of gear combinations. TDA allows tailoring the power of your truck to meet any variety of hauling conditions.

COMES TO TRUCKING

with TDA 2-speed axles

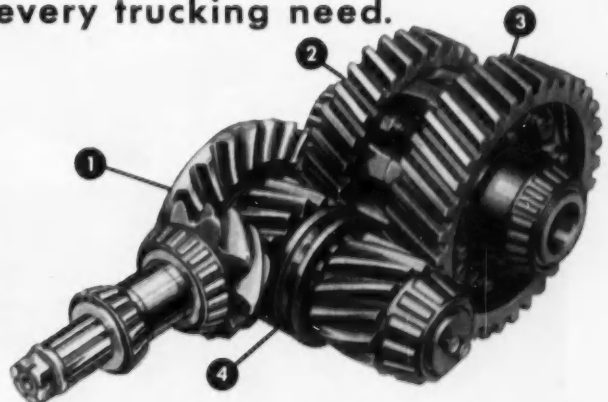
Exclusive, double-reduction design offers almost unlimited possibilities of gear ratios and ratio spreads—this versatility provides tailored power for every trucking need.

How TDA's extra "spread" works to your benefit. All 2-speed axles employ an extra set of gears to give two ranges of speed or power to choose from . . . one for *pulling power*, the other for fast speed. Most 2-speed axles offer only one choice of "spread"—37%. Design limitations prevent changing this standard "spread".

However, TDA uses the exclusive double-reduction design. With TDA, spreads are available all the way from 28% to 49%. This means that your axle can actually be tailored to give you just the power you need. Not only can you specify the spread most suited to your immediate trucking need—but you can easily *change* from one spread to another by merely changing the low speed helical pinion and gear—an *easy mechanical change*.

TDA's more efficient use of engine power gives important benefits . . . high road speeds, faster deliveries, better payload, and maximum fuel economy. No matter what your hauling problem or load/road conditions you save with TDA.

How TDA's 2-Speed principle works! A husky hypoid ring gear and pinion set (No. 1 above) provide the *first step* of the total gear reduction for both fast and slow ratios. Two large, heavy-duty helical gear sets provide the *second*



step. Both sets are of balanced size and capacity. One set (No. 2) is for fast speed; the other (No. 3) is for slow speed. The clutch collar (No. 4) power shifts to right or left to engage one helical pinion or the other.

Greater endurance, longer truck life with TDA. TDA's simple design eliminates small complicated parts and midget size gears. Large hypoid-helical design provides more teeth in contact—quieter operation and far less strain. Bearings are larger, too. All this adds up to more profitable operation under all conditions.



World's Largest Manufacturers of Axles for Trucks, Buses and Trailers
Plants at: Detroit, Michigan • Oshkosh, Wisconsin • Utica, New York • Ashtabula, Kenton and Newark, Ohio • New Castle, Pennsylvania

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Increase axle life with GENUINE TDA EQUIPMENT PARTS

Take no chances with ordinary replacement parts. For sure, dependable, factory-type jobs, specify genuine Timken-Detroit Axle parts kits—identical to your axles' original equipment.

Each kit is complete—gives you everything you need in one handy package. Gaskets and shims, brake liners and rivets, steering knuckles, king pins and bushings, differential nests—for every

size of brake and axle. Order by number from your dealer. Cut labor and adjustment costs. Get trucks back on the road quicker.



FAMOUS FOR POWER PACKAGES AND OVER 30,000 OTHER AIRCRAFT PARTS!

ROHR is famous as the world's largest producer of ready-to-install power packages for airplanes . . . like the Lockheed Constellation, Douglas DC-7, the all-jet Boeing B-52 and other great military and commercial planes.

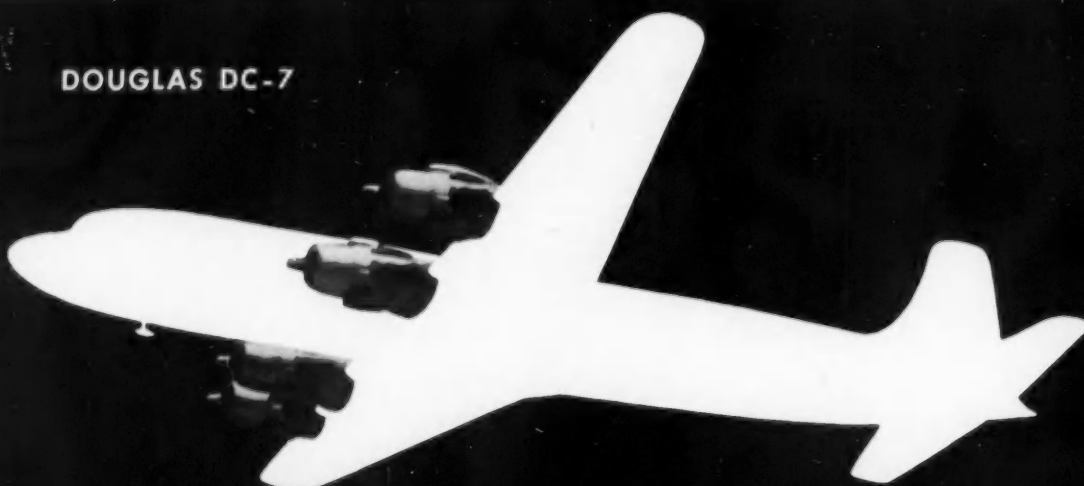
But that's not all! Today, in addition to power packages, ROHR'S engineering skill is going into the production of over 30,000

other different parts for aircraft of all kinds . . . many of these requiring highly specialized skill and equipment.

Whatever the aircraft part . . . whenever you need it . . . call on ROHR. Call on the engineering skill and production know-how gained from the thousands upon thousands of power packages and over 30,000 other aircraft parts that have made ROHR famous.



DOUGLAS DC-7



WORLD'S LARGEST PRODUCER

OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES
- RECIPROCATING, TURBO-PROP, TURBO-COMPOUND* AND JET

*A trade name of Curtiss-Wright



ROHR

AIRCRAFT CORPORATION

CHULA VISTA AND RIVERSIDE, CALIFORNIA

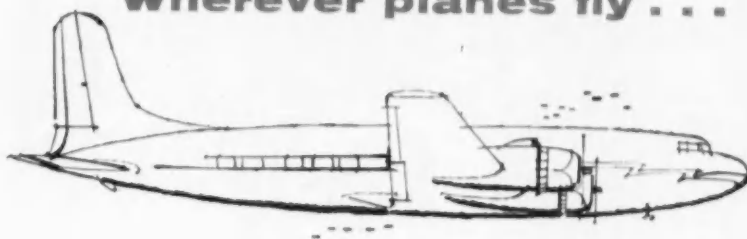


FLINT
1300 North Dart Highway
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General Motors Building

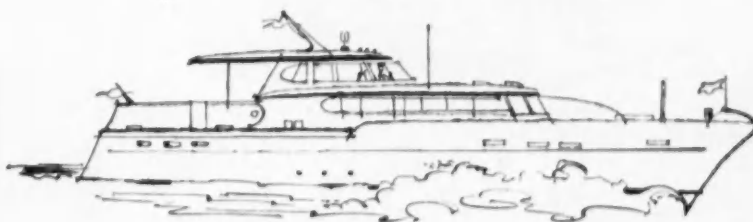
For More Than Twenty Years Nearly Every Make of Car Has Used One or More AC Products

ADAPTERS (Drive) • AIR CLEANERS • AIR CLEANERS AND SILENCERS (Combination) • AMMETERS • BREATHERS (Crankcase) • CAPS (Radiator Pressure) • FLEXIBLE SHAFT ASSEMBLIES • FUEL PUMPS • FUEL AND VACUUM BOOSTER PUMPS (Combination) • FUEL FILTERS & STRAINERS • GASOLINE STRAINERS • GAUGES—AIR (Pressure) • GAUGES—GASOLINE • GAUGES—OIL (Pressure) • GAUGES—TEMPERATURE (Water, Oil) • OIL FILTERS (Lube) • PANELS (Instrument) • RECIPROCATING VACUUM PUMPS • ROTARY VACUUM PUMPS • SPARK PLUGS • SPEEDOMETERS • TACHOMETERS • TERMINALS (Ignition Wire) • VALVES (Crankcase Ventilation)

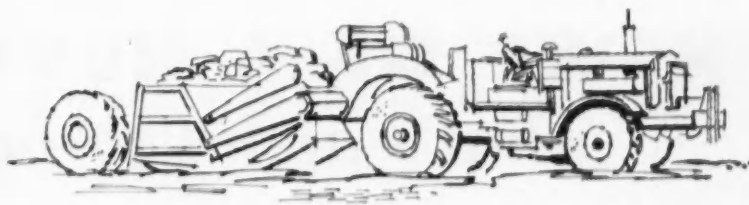
Wherever planes fly . . .



boats run . . .



or heavy tractors haul . . .



**AC TachOURmeters are
FIRST and FOREMOST!**

In maintaining heavy on or off-the-road equipment, distance traveled is not too important. What *is* important is total engine operating time. And, AC engineers reasoned, this should be *compensated* engine time, as greater wear naturally results from an engine run at high speeds than from one run at low speeds.

The result was the Tachourmeter first introduced by AC in 1944 . . . and now accepted as the standard wherever engine time must be logged.

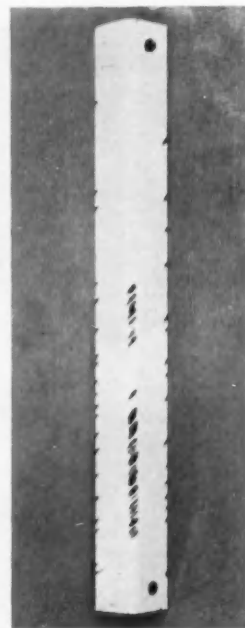
This is another example of AC's engineering imagination and know-how in action. Why not consult with AC engineers on any equipment problem you may face in your future planning?



AC SPARK PLUG DIVISION • GENERAL MOTORS CORPORATION



Enameling iron, with 1 coat of porcelain enamel over Parker Pre-Namel 410, was twisted 255° before enamel fractured.



Enameling iron, with conventional 2-coat system of porcelain enamel, fractured badly when twisted only 70°. (Twisted less than its elastic limit, metal returned to its original shape).

NEWS OF A REVOLUTION *that's about to happen!*

Porcelain enameling on steel has always been a preferred finish. However, its use has been limited by cost and by difficulties in the processing.

Now, a big change is about to take place. It is coming about through a cooperative effort that we feel should be acknowledged.

First, Parker Rust Proof Company's research discovered and developed a surface treatment for steel which permits the application of the porcelain enamel finish coat directly to ferrous metals, reduces cost, improves quality and eliminates many production difficulties in porcelain enameling. For production evaluation, Frigidaire Division of General Motors and Pemco Corporation

entered the effort with pilot runs and production tests.

The new treatment, making use of Parker Pre-Namel 410, has been shown to simplify porcelain enameling, achieve high quality uniform results, reduce use of frit, produce a more durable finish. Savings of from 1 to 3 cents per square foot of enameling surface are indicated.

We gratefully acknowledge the help we've had from Frigidaire and Pemco. Here is another instance of companies in diverse lines cooperating in a development program today which should benefit hundreds of manufacturers and millions of their customers in the future.

*Bonderite, Bonderlube, Parco, Parco Lubrite, Parker Pre-Namel—Reg. U.S. Pat. Off.



Since 1915—Leader in the Field

PARKER RUST PROOF COMPANY
2181 E. Milwaukee, Detroit 11, Michigan

BONDERITE
corrosion resistant
paint base

BONDERITE and BONDERLUBE
aids in cold forming
of metals

PARCO COMPOUND
rust resistant

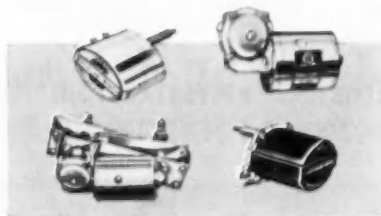
PARCO LUBRITE
wear resistant for friction
surfaces

TROPICAL
heavy duty maintenance
paints since 1883

**BAD WEATHER
PUTS DRIVERS**
behind the 8 ball



**UNLESS THEY'RE EQUIPPED WITH
AMERICAN BOSCH
CONSTANT ELECTRIC ACTION
WINDSHIELD WIPERS**



DUAL & SINGLE TYPES
For 6-12-24 Volt Systems. For Cars,
Trucks, Tractors, Buses and Boats.

Car and Truck drivers rack up more accident-free miles, even in the toughest weather, when they have constantly clear vision with American Bosch *Electric* Windshield Wipers. Regardless of speed or load, on up-grades and during acceleration, American Bosch *Constant Electric Action* is steady and dependable. Independent of engine vacuum, it eliminates stuttering, stalling blades—helps keep drivers in the clear and out of trouble on the road.

American Bosch Electric Wipers are in wide use as original equipment. There are Dual and Single types, models for large-size arms and blades up to 20" in length—dependable Windshield Wipers with the heavy duty construction that guarantees years of trouble-free service.

American Bosch Electric Windshield Wipers are today's positive answer to good vision in bad weather, and they offer a keen, sales-active feature for your vehicles. Ask for complete specifications. American Bosch, Springfield 7, Mass. A Division of American Bosch Arma Corporation.

AMERICAN BOSCH

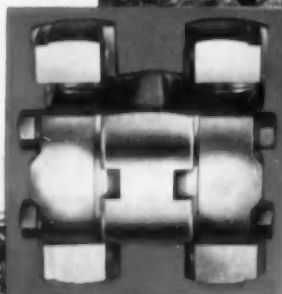
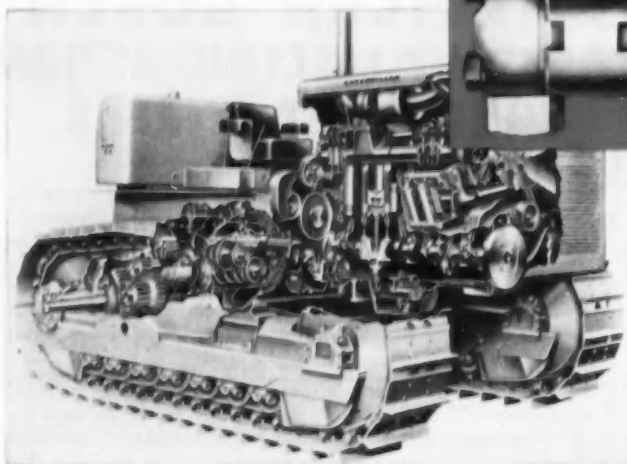


BEHEMOTH

All of the world's "biggest" tractors depend on MECHANICS Roller Bearing UNIVERSAL JOINTS to compensate for heavy-duty shocks and strains — severe enough to twist tractor frames. MECHANICS key-drive strength, flexibility and balance are unanimously specified by the largest tractor manufacturers to keep huge capacity machines operating long hours, day-after-day. They



The Cat D9 Tractor, shown below, sixth machine in Caterpillar's crawler line, is a 230-drawbar horsepower turbocharged tractor resulting from 10 years of big tractor research and development.



Thoroughly field tested during 1954, when Caterpillar put ten D9s on various jobs from coast to coast. This 56,000-pound machine has many earthmoving, construction, logging and pipe laying applications.

can't afford to permit large tractors and equipment to be kept idle by needless down-time. Let MECHANICS engineers help build reliability into your (200 to 50,000 foot pounds torque capacity) machines.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner • 2032 Harrison Ave., Rockford, Ill.

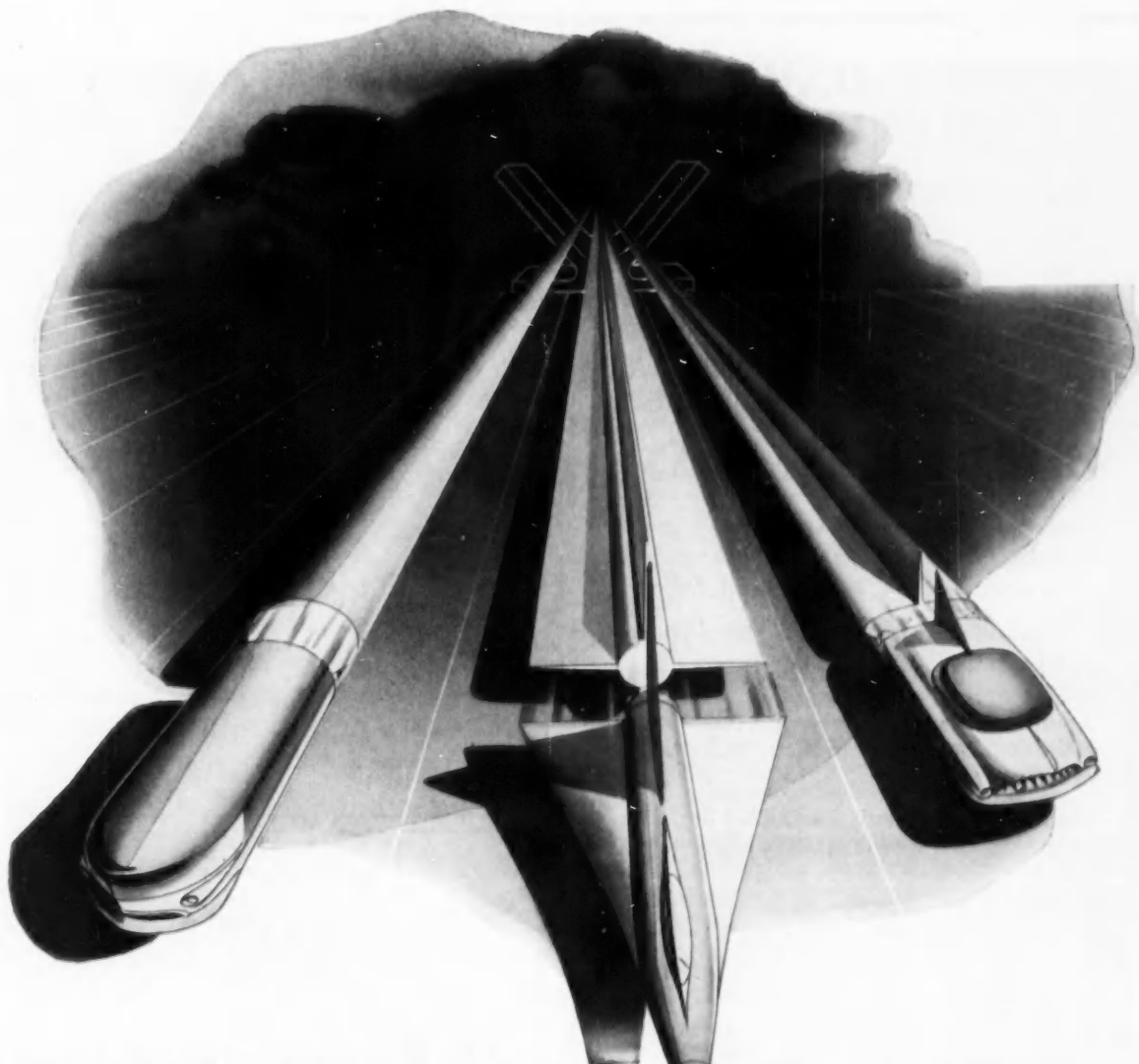
MECHANICS

Roller Bearing

UNIVERSAL JOINTS



For Cars • Trucks • Tractors • Farm Implements • Road Machinery •
Aircraft • Tanks • Busses and Industrial Equipment



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Designing with the future in mind? Look to extruded aluminum shapes to cut costs and improve your products. And look to Bridgeport for the very latest in ideas and manufacturing techniques.

We can extrude standard or specially engineered shapes in all extrusion alloys—with properties to meet your specifications. Our research and development teams are ready *now* to help you design for tomorrow's competition.

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BRIDGEPORT ALUMINUM

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Offices in Principal Cities

THE STANDARD OIL COMPANY (OHIO)

Manufacturing (Refining) Department

is looking for

CHEMICAL ENGINEERS, CHEMISTS, and MECHANICAL ENGINEERS

with one to five years experience in petroleum refining or related activities for staff work primarily in Cleveland, Ohio.

Possible employment in Toledo, Lima, or Cincinnati, also.

Applicant should have the following educational background and industrial experience:

Chemical Engineers: B.S. or higher degree and experience in development, pilot plant operation, process design, process trouble shooting, refinery process engineering, economic studies, or related work background.

Chemists: B.S. or higher degree and experience in product and process research or development.

Mechanical Engineers: B.S. or M.S. degree and experience in process equipment construction, design, inspection, or maintenance, petroleum product testing and field evaluation, or related work background.

Age range 22-32

Salaries commensurate with experience and level in organization. Advance on merit basis.

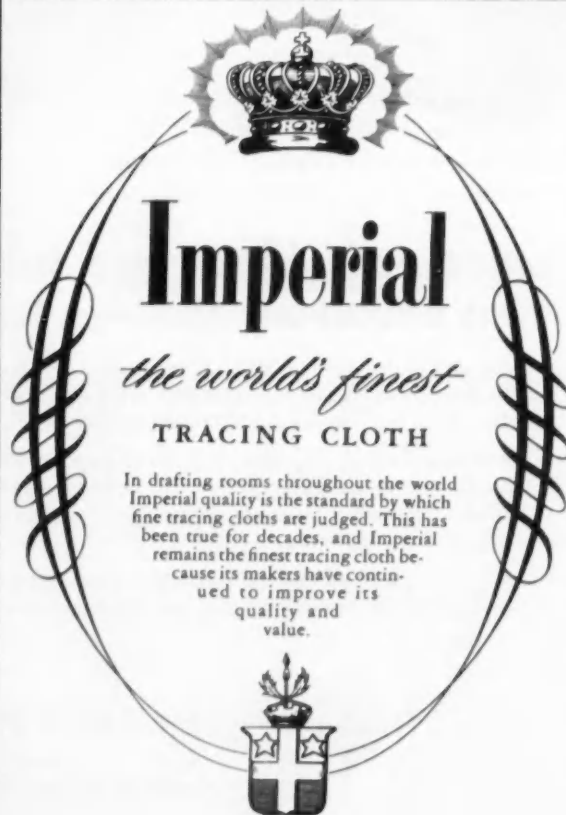
If you can qualify and are looking for a permanent job with a growing but secure midwest company, write, giving full information on education, industrial experience, military experience, and personal data to E. G. Glass, Jr., 1737 Midland Building, Cleveland 15, Ohio.

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- Challenging opportunities for fluid mechanics engineers in interesting research and development focused on, but not limited to, hydrodynamic propulsion, as well as broader fields of fluid mechanics.
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- Excellent working conditions in the world's largest water tunnel.
- Liberal vacation allowances and security benefit programs.

Send resume to:

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The PENNSYLVANIA STATE UNIVERSITY
ORDNANCE RESEARCH LABORATORY
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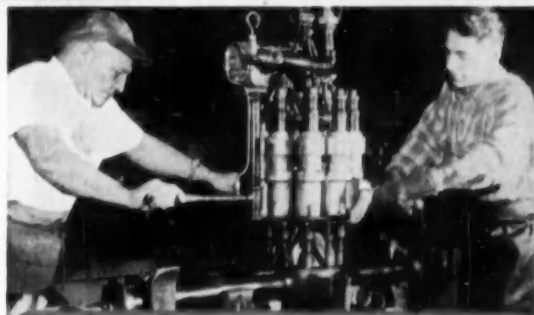
Fast, Accurate Nut Setting with MULTIPLE SPINDLES



Multiple nut setters bolt down cylinder heads in automobile engine assembly. Torque output of each spindle is individually adjustable.

Where bolts or nuts can be run and tightened two or more at a time, Keller Multiple Nut Setters increase output and reduce costs. Even more important, they improve quality control by keeping torque within very close tolerances.

The automotive industry—and many others—are making extensive use of these tools. For detailed information contact your nearest Keller sales office. Descriptive Bulletin 16-101 sent free on request.



Ten bolts are run simultaneously to attach axle carrier to differential housing. Accurate torque is vital because the joint must be leakproof.

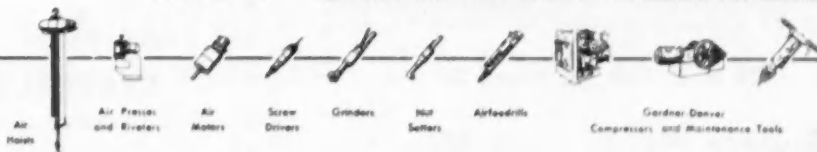


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DIVISION OF

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ENGINES.**

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*Vacuum cleaner
air filter and a
sweat band,
both with
sealed
edges.*

Thermoplastic man-made fibres can be felted and fabricated into special parts for assembly or use without further processing. The felt within the edges can have any desired porosity, within wide limits. Thus these fused-edge felts have great versatility, and are capable of rendering many different services. It will pay you to look into what they can do for you. Write for information on your company letterhead.

SOME PRESENT USES
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Insulation
Clothing lining
Fluid filters
(The field has barely
been scratched!)

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Company**



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design engineers

You'll find stimulation in the search for new ideas and different methods in the design and development of jet aircraft afterburners and nozzles with General Electric, one of the country's leading manufacturers of aircraft power plants, located in New England.

MECHANICAL DESIGN

For study and evaluation of mechanical data pertaining to design of aircraft gas turbines, including stress, heat transfer and mechanical studies on components. Requires experience with sheet metal, high speed rotating machinery compressors and related fields.

CONTROLS DESIGN & DEVELOPMENT

For design and analysis of complete systems and of components for jet engines, and general engine control evaluation. Controls are mainly pneumatic and hydraulic, including temperature sensing, feed back sensing, system stability and involves use of analog computers.

COMBUSTION EQUIPMENT

Design and development of jet aircraft afterburners and nozzles including problems in fuel system design and analysis, flame holder design, temperature problems, nozzle actuation and other related activities. Requires thorough knowledge of combustion fuels, heat transfer and thermodynamics.

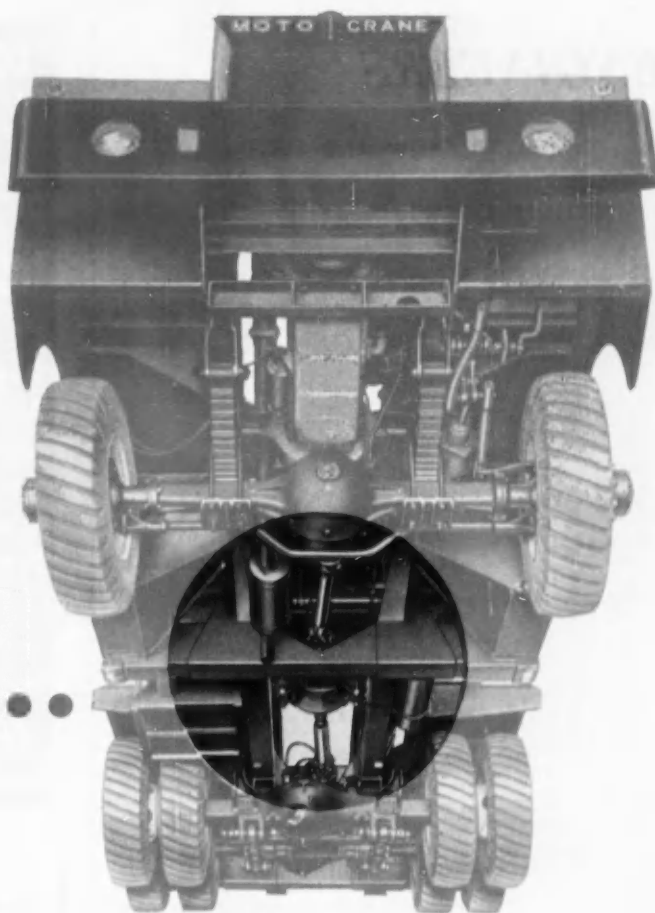
Qualified applicants are invited to send complete resumes to:

MR. DAVID B. PRICE
SMALL AIRCRAFT ENGINE DEPARTMENT

GENERAL ELECTRIC

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to BENEFIT the BUYER MOST...



**Lorain provides
dependable**

BLOOD BROTHERS propeller shafts

Speed, economy, mobility—all benefit truck-crane users. But *most* essential is *dependability*, which protects the owner's profits.

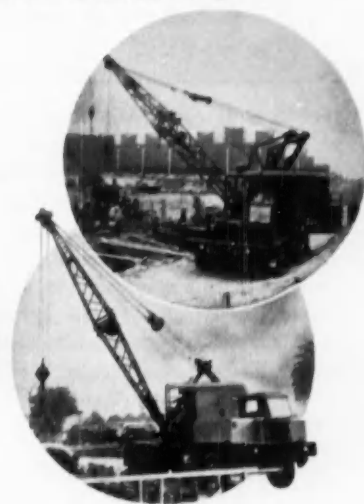
On these rugged Lorain Moto-Cranes, the Thew Shovel Company assures *outstanding* dependability . . . right down to specifying Blood Brothers Propeller Shafts. Over the years, they've proved their ability to transmit heavy torque loads despite the toughest on-or-off-the-road conditions—to benefit the buyer *most!*

If *you* have universal joint or propeller shaft problems, write or call Blood Brothers. We'll gladly offer engineering suggestions.



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MACHINE DIVISION**

ROCKWELL SPRING AND AXLE COMPANY
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UNIVERSAL JOINTS
AND DRIVE LINE
ASSEMBLIES

ENGINEERS

INVITED TO GROW AND BUILD A CAREER
WITH AN EXPANDING DIVISION OF GENERAL
MOTORS IN PLEASANT RESIDENTIAL CITY IN
WESTERN NEW YORK STATE.

We Need

- **MECHANICAL DESIGN ENGINEERS** —
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to design, coordinate and control
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9 NEW and 4 REVISED Aeronautical Standards & Recommended Practices

were issued
July 1, 1955

30 NEW and 37 REVISED Aeronautical Material Specifications

were issued
March 1, 1955

For further information please write

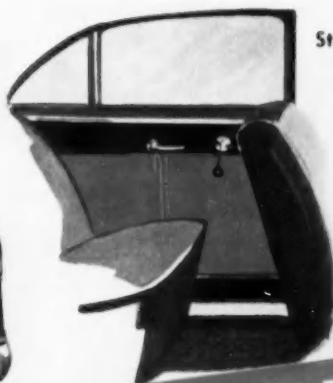
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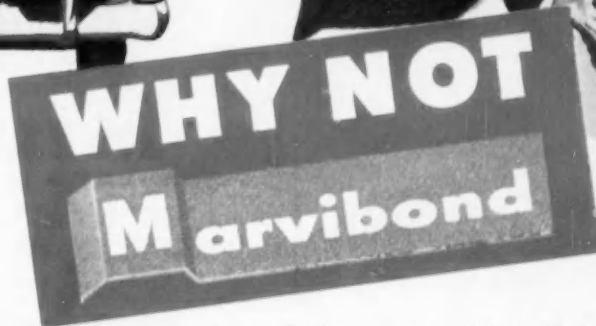
Stationwagon roof panels



Stationwagon side panels



Taxicab divider panels



the new vinyl-to-metal laminating process?

Larger families... more rough 'n tumble in the back seat.

Smaller taxicabs... more knocks and scrapes from suitcases and boxes.

Increased stationwagon registrations... more scuffs and bruises from bigger, shifting packages.

These three trends emphasize the importance of new protective materials like Marvibonded metals. Marvibond® is the new laminating process that permanently bonds vinyl sheeting to practically any kind of metal.



Seat backs and frames

Marvibond vinyl-to-metal laminates...

- can't rust, rot or corrode! • are attractive, pleasant to touch!
- can't chip, crack, or craze! • are scuff- and stain-resistant!
- are clean, comfortable, easy to maintain!

Prefinished sheet metal! Marvibonded metals are laminated before forming. Neither finish nor bond is affected by bending, crimping, drilling, embossing, punching, or drawing.

Practically any surface effect! High finish or matte finishes, leather-like grains, marble patterns, prints, weaves, and sculptured appearances can be achieved economically.

Marvibonded laminates can be used where sheet metal is used...dashboards, window trim, door panels, truck cabs, and other automotive interior components. So, why not consider what the Marvibond process offers in beauty, protection, serviceability, extra sales impetus and real production economies? For technical data and samples, and the names of licensed Marvibond laminators in your area, please write—

*Patent applied for



Naugatuck Chemical

Division of United States Rubber Company
Naugatuck, Connecticut



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Job-Fitted

IN DESIGN AND CONVENIENCE

Here is a sturdy, medium priced pedestal seat that will 'fill the bill' for panel trucks, and many other types of mobile equipment.

Contour seat padded with foam rubber, covered with genuine black flexible leather. Manual vertical adjustment. Base of pedestal will be engineered for adaptation to your particular application.

Write today for a MilSCO cushion seat catalog showing the complete line of MilSCO seating.

Sold only to manufacturers of original equipment.



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That's about all you have to do to contact one of Milford's 5 plants or 20 offices! And Milford means fast deliveries, top quality and service — always!

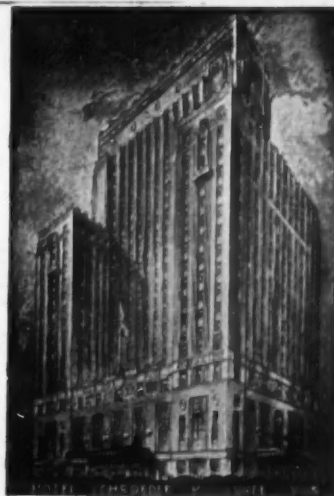
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RIVET & MACHINE CO.

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Headquarters for RIVETS

Tubular, split and special cold-formed
and Rivet-setting Machines



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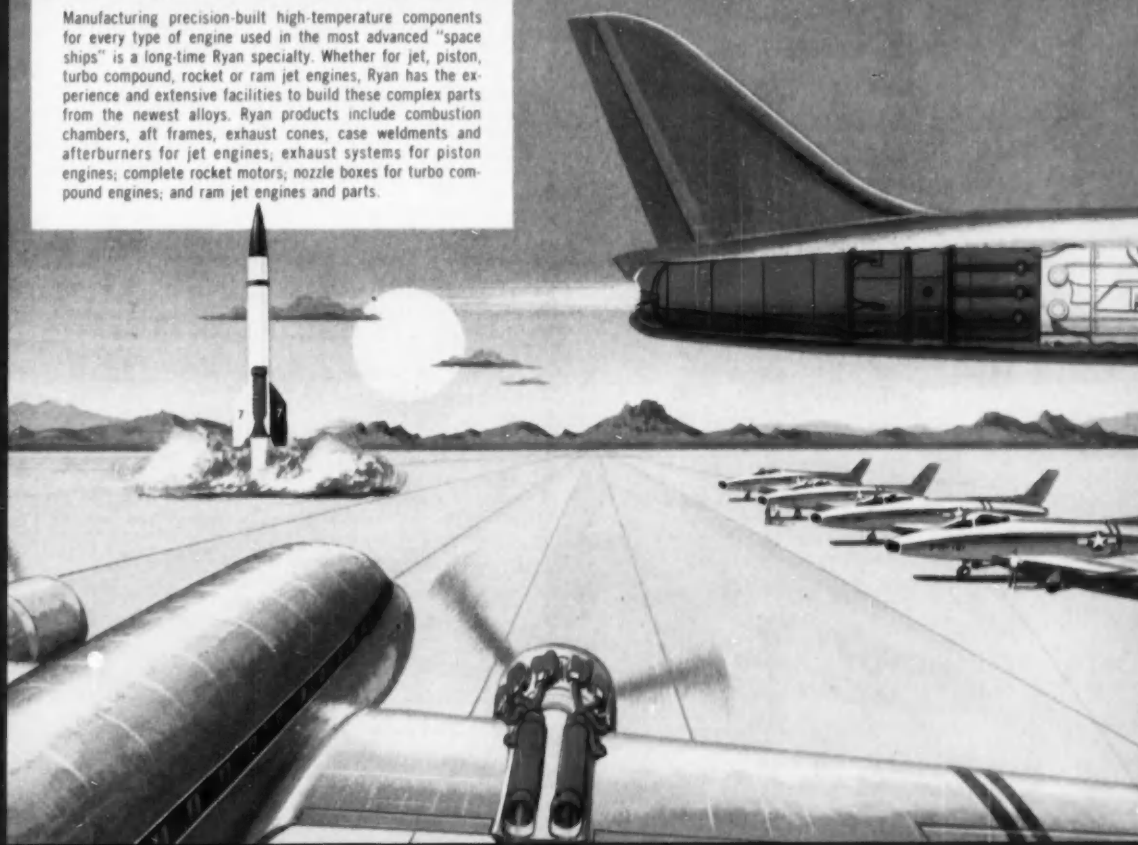
TVA needs a competent Fleet Engineer in its Transportation Branch located at Chattanooga, Tennessee.

The salary is \$5625 per year for a 40-hour workweek, with automatic within-grade increases for satisfactory service. Vacation, sick leave, and retirement benefits. This is diversified work including maintenance engineering, field observation, shop operations, and limited test and experimental work on automobiles, construction and marine equipment, and airplanes.

Applicants must have a bachelor's degree in Automotive Engineering, Mechanical Engineering, or Electrical Engineering; and three years of practical experience in fleet, service, or maintenance engineering. Interested candidates should write to Tennessee Valley Authority, Examining Section, Knoxville, Tennessee.

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Manufacturing precision-built high-temperature components for every type of engine used in the most advanced "space ships" is a long-time Ryan specialty. Whether for jet, piston, turbo compound, rocket or ram jet engines, Ryan has the experience and extensive facilities to build these complex parts from the newest alloys. Ryan products include combustion chambers, aft frames, exhaust cones, case weldments and afterburners for jet engines; exhaust systems for piston engines; complete rocket motors; nozzle boxes for turbo compound engines; and ram jet engines and parts.



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METALLURGICAL ENGINEERING 	WEAPONS SYSTEMS 	ROCKET MOTORS & RAM JETS 	AIRCRAFT EXHAUST & DUCTING SYSTEMS 	

ENGINEERS

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Senior Research Engineer—Structures

B.S. degree in aeronautical engineering or applied mechanics with minimum of 3-5 years experience in structural development and theoretical stress analysis. Work includes theoretical and experimental analyses of problems in thermal stresses, structural stability, creep-buckling and fatigue.

Stress Section

Senior Stress Analysis Methods Engineer

B.S. or M.S. in aeronautical or civil engineering, with advanced mathematics background and with a minimum of 3 years experience in airframe stress analysis, or structural methods.

Aircraft Design

Wind Tunnel Model Designer

Mechanical Engineer for wind tunnel model design experienced in intricate mechanisms, application of materials used in high speed model design, and ingenuity to originate testing devices. 3 to 5 years experience and college degree preferred.

Please address complete resume, outlining details of your technical background, to:

- Assistant Chief Engineer
- Administration
- Mr. R. L. Bortner



REPUBLIC AVIATION
FARMINGDALE, LONG ISLAND, NEW YORK

ENGINEERS

Growing demand for jet engines leading to the expansion of this department of a major company, located in the Midwest, has created openings for the following engineers:

MECHANICAL—Thermodynamic Calculations on Jet Engines.

For calculation of thermodynamic cycle of jet engines. Will learn to calculate on IBM computers the relation of compressor ratio, turbine inlet temperature, effect of heat, etc. on engine thrust and SFC.

MECHANICAL—Able To Learn Design Of Rotating Parts For Jet Engines.

For mechanical design of rotating parts (compressor discs, blades, etc.) on prototype jet engines. Will learn to run stress calculations on IBM computers, to re-design to stay within yield point of material, to calculate "G" and gyro loading stresses caused by combat maneuvers and stresses caused by thermal gradients.

MECHANICAL or ELECTRICAL—Control Systems Design For Jet Engines.

For initial design of jet engine control systems involving parametric analysis of engine parameters (rotor RPM, turbine inlet temperature, etc.), parametric scheduling based on parametric analysis, and stability analysis. Requires aptitude for handling differential equations.

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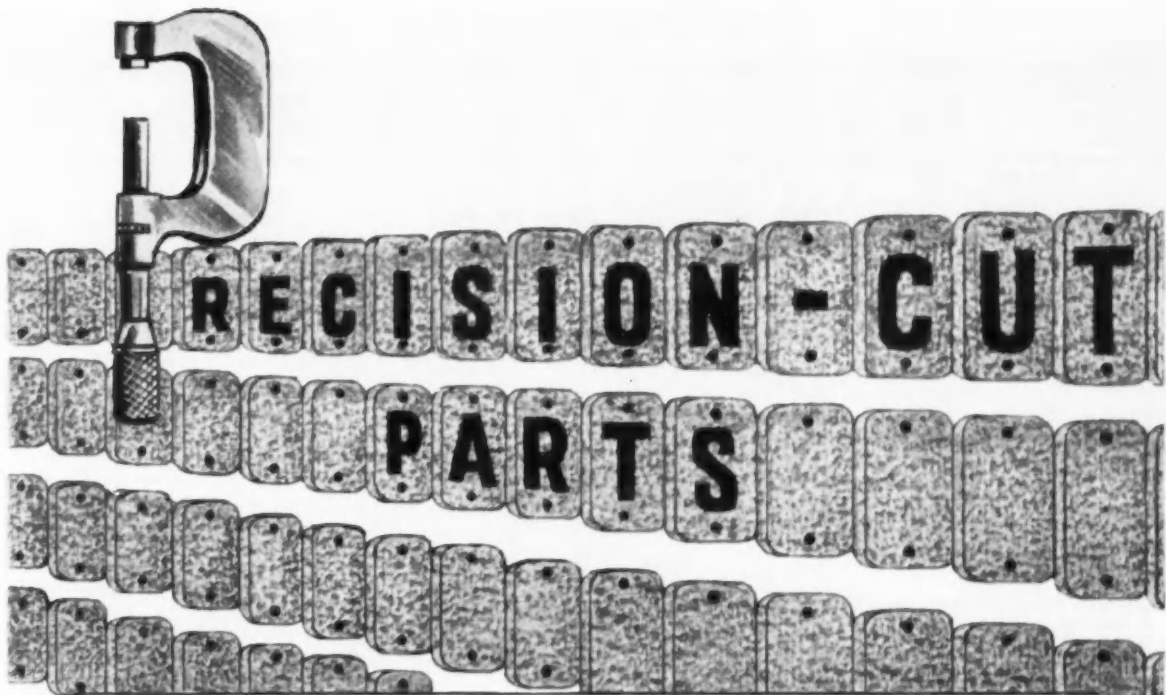
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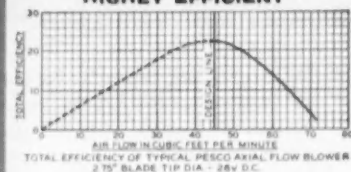
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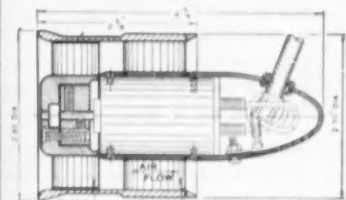
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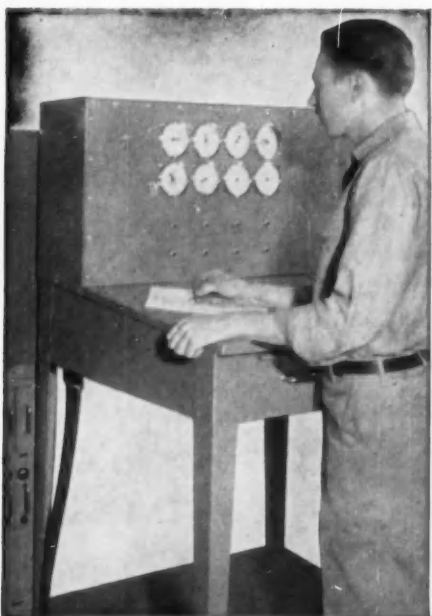


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